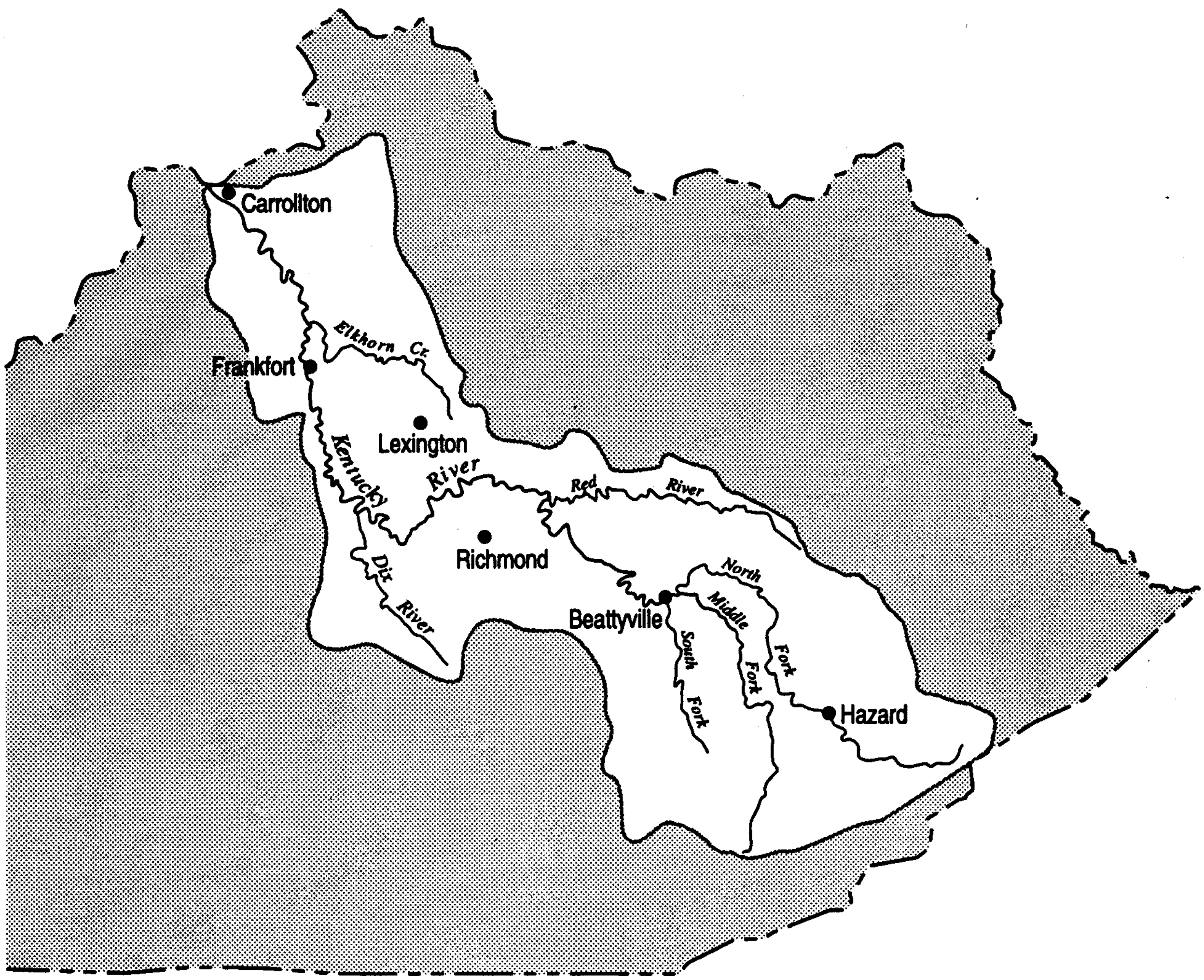
WATER QUALITY IN THE KENTUCKY RIVER BASIN

DANIEL I. CAREY



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Donald C. Haney, State Geologist and Director
UNIVERSITY OF KENTUCKY, Lexington

in cooperation with
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Daniel I. Carey

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FOREWORD

Water-quality management decisions, which touch the lives of everyone either directly or indirectly, must be based on public consensus to be effective. Obtaining a consensus on issues that are of common concern but extend beyond the boundaries of individual communities will require that the public be provided with information from which to make informed judgments. Information must be provided in understandable, non-technical language. This report provides a starting point from which to begin evaluating water-quality issues in the Kentucky River Basin. The impetus for this summary was provided by the Kentucky River Authority, which, by statute, bears the ultimate burden of responsibility for water-quality maintenance in the basin.

The Kentucky River and its tributaries provide the life blood to the body of the basin. The streams provide sustaining water for communities, commerce, and agriculture. They also provide sustenance for the spirit through their natural beauty and recreational opportunities--boating, swimming, and fishing. The streams also convey wastes from the body of the basin-human and animal wastes, grease, oil and combustion by-products flushed from city streets, industrial wastes, pesticides, herbicides and fertilizers from home and farm use, natural detritus, and countless others.

Five hundred years ago perhaps 3,500 people lived in the basin, and their activities had little impact on streams. Today, about 600,000 people live in the basin, and streams in many areas are polluted.

For the past 20 years, more and more regulations have been developed in an attempt to control the dumping of wastes into streams. During that time population and developmental pressures have increased. Environmental control and the treatment of wastes have become more complex and more costly. Environmental agencies seem to lack the resources to adequately address the current issues (Kentucky Department for Environmental Protection, 1989). Continued population growth and development will require even more resources to treat wastes and to regulate waste disposal.

The amount of waste a stream can absorb and still provide clean water is limited. There are also practical limits to waste treatment: it is not possible to remove 100 percent of the wastes before discharge to a stream. Therefore, the total amount of wastes that can be generated and satisfactorily treated is limited.

Sources of pollution that do not enter streams at known points, such as runoff from agricultural areas, are difficult, if not impossible, to control. Such nonpoint sources significantly affect water quality. It has become clear that in addition to regulating discharges to streams, activities that can produce pollutants that will be washed to streams or drained to ground water must also be managed. The responsible use of pesticides, herbicides, and fertilizers, for instance, will reduce the amount of these chemicals entering streams and ground water. Impacts on water quality must also be considered when deciding issues of industrial or commercial development, population growth, and land use. Locating new development outside of sensitive ground-water recharge areas or away from overloaded stream segments will also help maintain water quality.

New institutional and financing approaches will also be required to effectively manage water quality. Economists and environmentalists have explored a variety of pollution-control and prevention policies based on economic incentives. These approaches need to be further examined for application to Kentucky. New approaches and financing methods for waste treatment in small municipalities and rural areas are also needed.

A comprehensive water-quality management plan must incorporate an entire river basin. A first step in the Kentucky River Basin would be to establish general water-quality policies based on a consensus of interested parties within the basin. These policies could provide the basis for the development of water-quality management plans that would reflect both local and basinwide issues and concerns. Water-resource management decisions will not be easy or always popular, but will be necessary to create an environment that will enhance the quality of life in the basin.

CONTENTS

CONTENTS
(continued)

ILLUSTRATIONS

Figure **Page**

TABLES

Table **Page**

TABLES
(continued)

Table **Page**

WATER QUALITY IN THE KENTUCKY RIVER BASIN

Daniel I. Carey

ABSTRACT

Data gathered up to 1990 suggest that water pollution problems existed throughout the Kentucky River Basin. Fecal coliform bacteria in streams was a widespread problem because of the inadequate treatment of municipal wastes, failing septic systems, and agricultural runoff. Iron, lead, manganese, mercury, and silver exceeded State standards and Federal guidelines for drinking water and aquatic life at most of the sample sites for a majority of samples. Aquatic life in many smaller streams in the Knobs region was reduced by chloride discharges from oil and gas operations, according to the Kentucky Division of Water. Organic enrichment and high nutrient loads from waste-water treatment plants and farms reduced aquatic life in the Blue Grass region. Several locations were affected by unknown toxins, and detectible levels of heavy metals and the organic pesticides chlordane, aldrin, dieldrin, and DDT were found in fish tissues from the Kentucky River.

In the Kentucky Environmental Management Plan, 1990-92, the Division of Water identified several water-quality issues: the timely issuance of permits and assuring that permits were complied with; improving the control of toxins and chlorides; responding to the proliferation of package waste-water treatment plants and combined sewer/storm water systems; assuring compliance with new, more stringent drinking-water requirements; improving the monitoring network; improving the Wild Rivers Program; and responding to cuts in Federal funding. To address these issues and meet the demands of new regulations and programs required an increase in personnel and funding of about 50 percent.

An increasing number of actual and potential pollutants are being identified and regulated. The Kentucky Department for Environmental Protection recognized that the current regulatory approach could not be indefinitely sustained. Environmental protection to date has focused on treating air and water emissions at the end of the pipe or safely disposing of waste after it is produced. We are discovering that the superior approach is to eliminate or reduce waste ***before*** **it is generated.**

The Department also recognized that transforming waste streams is often counterproductive. Reducing pollutants in water discharges may increase the land disposal problem. Burning wastes reduces the quantity for land disposal, but may increase toxic concentrations of solids to be disposed of, or produce unacceptable air pollutants. Waste cannot be made to disappear, but must be dispersed or diluted by the environment. Excessive concentrations of waste may produce irreversible damage to the environment.

The severity of water-quality problems in many parts of the Kentucky River Basin has been reduced during the past 20 years. Brine discharges from oil and gas operations have reportedly been reduced. Chronic problems at some waste-water treatment plants, such as the Lexington facility on Town Branch, have diminished. It is clear, however, that despite the best efforts of such agencies as the Division of Water and the Kentucky Nature Preserves Commission, water-quality problems in the basin continue to be widespread and persistent.

INTRODUCTION

This report summarizes the most recently published information on water quality and water-quality regulation in the Kentucky River Basin. Information was obtained from the "1990 Report to Congress on Water Quality" by the Kentucky Division of Water, which evaluated streams throughout the State to determine if water quality was adequate to support fishing, swimming, and boating (equivalent to the regulatory categories of warm-water aquatic habitat, primary contact recreation, and secondary contact recreation); "Surface Water-Quality Assessment of the Kentucky River Basin, Kentucky: Analysis of Available Water-Quality Data through 1986" (Smoot and others, 1990), which compared concentrations of potential pollutants with State and Federal standards for clean water; and "Summary of Biological Investigations Relating to Surface-Water Quality in the Kentucky River Basin, Kentucky" (Bradfield and Porter, 1990), which reviewed available data on the aquatic life of streams in the basin and the resulting water quality. An overview of the water-quality regulatory activities of the Kentucky Division of Water was taken from the Kentucky Environmental Management Plan, 1990-1992 (Kentucky Department for Environmental Protection, 1989). All four documents are recommended for a more detailed study of water quality in the basin and for an extensive list of data sources.

Some changes in water quality at specific locations have no doubt occurred since the data were published. In general, however, this summary presents either current conditions, or conditions that have occurred during the past 20 years and have the potential to recur. As a summary, this report is by definition incomplete. Waterquality professionals will no doubt be disturbed by some omissions. The purpose of this report is, however, to provide a starting point for the understanding of water-quality issues in the Kentucky River Basin. From this starting point it is hoped that the public can become meaningfully involved in water-quality decisions.

DESIGNATED USES OF STREAMS

What does "clean water' mean? The Federal Water Pollution Control Act of 1972 (FWPCA, 1972) put forth two national goals: by July 1, 1983, wherever attainable, water quality should provide for the protection and propagation of fish, shellfish, and wildlife and provide for recreation in and out of the Nation's waters; and, by December 31, 1985, the discharge of pollutants into all navigable waters would be eliminated. These goals provide a reasonable definition of clean water and how it should be maintained. They have yet to be achieved.

Stream-use designations, which have been assigned to all stream segments in the Kentucky River Basin, are used to define the clean-water goals. With the exception of the specific designations shown in Table 1, all streams are designated for the use of warm-water aquatic habitat (fishing), primary contact recreation (swimming), secondary contact recreation (boating), and domestic water supply.

Table 1.—Stream–Use Designations in the Kentucky River Basin. From Kentucky Natural Resources and Environmental Protection Cabinet (1991).

Stream Name	*Stream Segment*	*Use Designation*
Chimney Top Creek	basin	CAH, PCR, SCR
East Fork, Indian Creek	source to Indian Creek	CAH, PCR, SCR
Gladie Creek	basin	CAH, PCR, SCR
Middle Fork, Red River	source to river mile 10.6	CAH, PCR, SCR
Parched Corn Creek	source to Red River	CAH, PCR, SCR
Red River	river mile 68.6 to 59.5	WAH, PCR, SCR, ORW
Dix River	Herrington Lake Dam to Kentucky River	CAH, PCR, SCR
Swift Camp Creek	source to Red River	CAH, PCR, SCR

Notes: SCR: Secondary Contact Recreation
WAH: Warm–Water Aquatic Habitat
CAH: Cold–Water Aquatic Habitat
PCR: Primary Contact Recreation
ORW: Outstanding Resource Water

The 1990 Kentucky Report to Congress on Water Quality (Kentucky Division of Water, 1990) assessed the extent to which streams in the Kentucky River Basin achieved the use categories discussed above. Of the 3,416 stream miles in the Kentucky River Basin depicted on the Hydrologic Unit Map (U.S. Geological Survey, 1974), 1,698.5 stream miles (49.7 percent) were assessed. Of the assessed stream miles, 323.3 miles (19 percent) did not support designated uses and 231.5 miles (13.6 percent) only partially supported designated uses. Assuming that streams that were not assessed were similar to those that were, about 1,115 miles of streams (32.6 percent) in the Kentucky River Basin did not fully meet designated uses.

Table 2 shows the streams in the Kentucky River Basin that did not support designated uses, and the causes and sources of the problems. Where primary contact recreation was not supported in the basin, the major cause was fecal coliform bacteria contamination. Sources identified were municipal waste-water treatment plants, agriculture, septic systems, and urban runoff. Fort Boonesborough State Park beach was closed to swimming for the season on July 9, 1988, because of drought conditions and bacterial contamination of the Kentucky River. The beach was again closed for the season on July 27, 1989, and July 6, 1990, because of bacterial contamination of the river.

Table 2.—Streams in the Kentucky River Basin That Do Not Support Designated Uses. From Kentucky Division of Water (1990).

Stream	*Aquatic Life (miles)*	*Cause*	*Source*	*Recreation (miles)*	*Cause*	*Source*
North Fork, Kentucky River	8.6	siltation	mining/agriculture	46.1	pathogens	municipal/ urban runoff
Lost Creek	18.5	siltation	mining			
Spring Fork, Quicksand Creek	15.0	siltation	mining			
South Fork, Quicksand Creek				13.8	pathogens	agriculture
Quicksand Creek				20.8	pathogens	agriculture
Troublesome Creek				49.5	pathogens	municipal/ septic tanks
Rockhouse Creek	24.3	siltation	mining			
Middle Fork, Kentucky River				43.2	pathogens	agriculture
Raccoon Creek	8.5	oil and grease/ siltation	petroleum activities/mining			
Cutshin Creek	28.8	oil and grease/ siltation	petroleum activities/mining			
Kentucky River at Heidelberg				28.3	pathogens	municipal/ agriculture
Kentucky River at Camp Nelson				37.7	pathogens	unknown
Kentucky River at Frankfort				30.1	pathogens	unknown
Red River	34.3	siltation/ metals	habitat damage/ mining	10.1	pathogens	municipal
South Fork, Red River	11.8	chlorides	petroleum activities			
Sand Lick Fork	5.0	chlorides	petroleum activities			
Billey Fork	8.6	chlorides	petroleum activities			
Millers Creek	6.4	chlorides	petroleum activities			
Big Sinking Creek	14.1	chlorides	petroleum activities			

Continued on next page.

Table 2.—Continued.

Stream	*Aquatic Life (miles)*	*Cause*	*Source*	*Recreation (miles)*	*Cause*	*Source*
North Elkhorn Creek	2.0	organic enrichment/chlorine/ nutrients	municipal			
Cane Run	17.4	unknown toxicity	unknown			
South Elkhorn Creek	41.0	organic enrichment/metals	municipal	17.6	pathogens	municipal/ urban runoff
Town Branch	11.3	organic enrichment/metals	municipal	11.3	pathogens	municipal
Dix River				13.5	pathogens	municipal
Clarks Run	8.0	organic enrichment/unknown toxicity	municipal			
Silver Creek	2.0	organic enrichment/nutrients	municipal			
Walnut Meadow Branch	3.6	organic enrichment/nutrients	municipal			
Brushy Fork	0.2	nutrients	municipal			

Organic enrichment, siltation, and chlorides degraded warm–water aquatic habitats. Municipal point sources were primarily responsible for organic enrichment. An estimated 36,000 fish were killed by organic enrichment in West Hickman Creek in 1988 (Table 3), and an unknown number of fish were killed in East Hickman Creek in 1989. Surface mining and agriculture were the major causes of siltation. In addition to the streams listed in Table 2, Carr Fork and Buckhorn Lakes only partially supported recreation because of high sediment concentrations. Oil and gas operations were the primary sources for chloride pollution in the Red River Basin.

Metals from point discharges also reduced water quality. The Lexington sewage treatment plant discharged lead and copper to Town Branch, and North American Phillips Lighting, near Danville, was cited as discharging lead. The North Fork of the Kentucky River, Red River, Town Branch, and South Elkhorn Creek were also listed as affected by zinc. The aquatic habitat for virtually the entire length of Cane Run, a tributary to North Elkhorn Creek, was listed as impaired because of an unknown toxicity from an unknown source.

In addition to the streams listed in Table 2, excessive nutrients adversely affected aquatic life and recreation in Wilgreen, Carr Fork, and Herrington Lakes. Herrington Lake received excessive nutrients from municipal discharges, septic systems, and agriculture, and Wilgreen Lake was affected by septic systems. Fish kills in Herrington Lake for 1988–89 caused by excessive nutrients (eutrophy) and an unknown cause are listed in Table 3.

Pollution of streams, lakes, wetlands, and ground water from nonpoint sources (agriculture, mining, oil and gas operations, urban runoff, septic systems, etc.) was also assessed in the 1990 Report to Congress (KDOW, 1990). Affected waters are shown in Appendix A. "Monitored" waters were assessed based on recent site–specific water–quality data. Most of the "evaluated" waters were based on data obtained from the 1987 Nonpoint Source Pollution Survey (discussed in Kentucky Division of Water, 1989a).

Nonpoint–source (NPS) categories shown in Appendix A are ranked, with "1" being the most severe. Coal–mining and petroleum–recovery activities are the most significant sources of nonpoint water pollution in the North (KY05100201–), Middle (KY05100202–), and South Forks (KY05100203–) of the Kentucky River. The NPS category "80–Other" in most cases represents solid waste and sewage. This category was not listed in the 1987 NPS questionnaire, but was written in by respondents. Solid waste, which primarily clogs water courses and creates eyesores, can also be a water–quality problem when it includes substances that can

Table 3.—Summary of Fish–Kill Investigations in the Kentucky River Basin in 1988–89.					
County	*Water Body*	*Number Killed*	*Date*	*Miles*	*Cause*
Boyle	Herrington Lake	2,000	4–28–89	5.00	unknown
Boyle	Herrington Lake	2,000	9–17–89	4.00	eutrophy (natural)
Fayette	North Elkhorn Creek	unknown	6–01–89	2.00	unknown
Fayette	West Hickman Creek	36,268	6–14–88	2.27	waste–water treatment plant organic enrichment
Fayette	West Hickman Creek	17,200	4–23–89	2.00	chlorine
Fayette	East Hickman Creek	unknown	8–03–89	—	organic enrichment
Fayette	Reservoirs 2, 3	unknown	5–12–89	—	unknown
Franklin	Kentucky River	2,538	8–19–88	0.37	unknown
Harlan	Greasy Creek	6,159	6–21–88	1.50	coal–mine subsidence
Madison	Otter Creek	18,000	10–31–89	11.75	ammonia
Scott	North Elkhorn Creek	unknown	7–15–88	1.00	eutrophy (natural)

pollute the water. Sediment, bacteria, nutrients, chlorides, sulfates, and metals affect aquatic life and recreation in the eastern Kentucky region.

Agriculture, petroleum, and mining activities are the primary nonpoint-source polluters in the Knobs region (KY05100204-). Sediment, chlorides, metals, sulfates, nutrients, and bacteria affect aquatic life and recreation uses in the region.

Croplands and pasture, land development, urban runoff, solidwaste and sewage, andon-sitewaste-water systems are the primary sources of nonpoint pollution in the Blue Grass region (KY05100205-). Sediment, nutrients, and bacteria affect aquatic life and water recreation in the region.

CHEMICALS AND BACTERIA

The most recent and comprehensive analysis of water-quality data in the Kentucky River Basin was completed in 1990 by the U.S. Geological Survey (Smoot and others, 1990). This study evaluated all available water-quality data for the basin through 1986. The primary data for the study were collected from 1976 to 1986 at the sites shown in Figure 1 and listed in Table 4. The study made a generalized assessment of common water-quality properties and constituents such as pH, alkalinity, major ions, nutrients, selected major metals, trace elements, and fecal coliform bacteria. These data were used to assess, among other things, how often waters at sample points did not meet Federal and State water-quality standards and therefore did not support designated uses. The percentage of samples not meeting guidelines is given in Appendix B.

The data in Appendix B show that throughout the basin regulatory standards and guidelines were frequently not met. Elevated levels of iron, lead, manganese, mercury, silver, and fecal coliform bacteria were observed at virtually all of the sample sites.

LIFE IN STREAMS

Bradfield and Porter (1990) examined water quality in the basin from a biological perspective. Biological surveys provide a direct look at the impacts of water quality on stream life. Aside from the technical scientific names (*see* Glossary for definitions of selected terms), biological surveys provide the average person with a better feel for water-quality impacts than chemical analyses do. The fact that a stream has no fish is more graphic than a number representing chloride concentration. Biologists have developed procedures for determining the health of a stream based on the types, numbers, diversity, distribution, and pollution tolerances of organisms living there. The following discussion is based on Bradfield and Porter (1990).

Algal communities can reflect short-term (days to months) changes in water quality. For example, streams affected by oikfield brines frequently are dominated by *halophific* (salt-loving) diatoms. Streams that receive sewage effluents often have dense growths of algae types that dominate in nutrient-enriched waters,

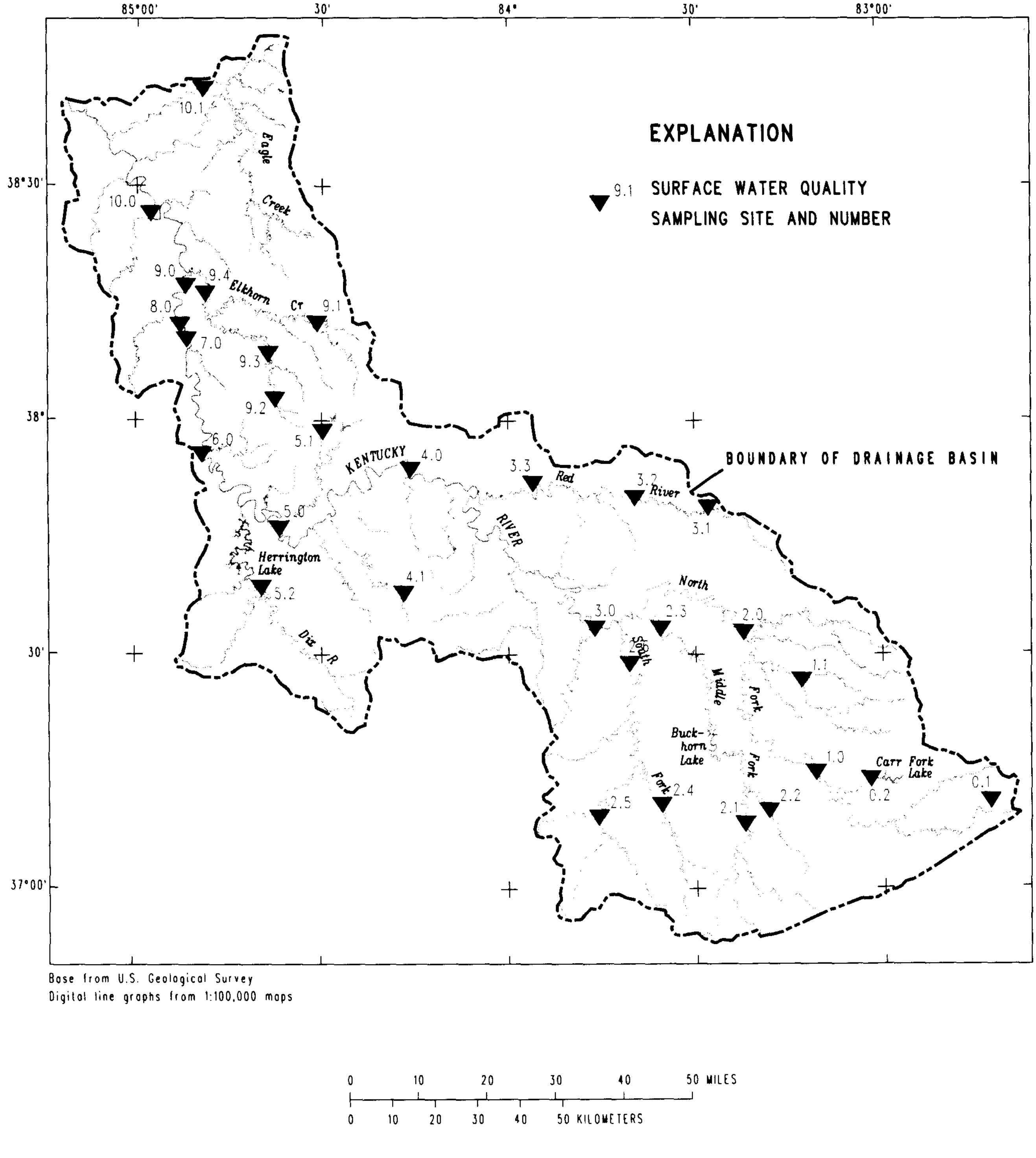

Figure 1. Locations of surface-water-quality sampling sites in the Kentucky River Basin at which 10 or more samples were collected, 1976–86. From Smoot and others (1990).

and streams subjected to organic enrichment contain *heterotrophic algae* (able to convert carbon compounds to energy). The effects of sedimentation can be seen by the dominance of epipefic algae (associated with sediments). Most undisturbed streams in eastern Kentucky contain epilithic (attached to rocks) and epiphytic (attached to filamentous algae and aquatic plants) diatoms.

Table 4.—Surface–Water–Quality Sampling Sites in the Kentucky River Basin. From Smoot and others (1990).

Site Number	*Kentucky River Mile*	*Station Number*	*Station Name*	*Drainage Area (square miles)*
	417.3		BOONE FORK BASIN	19.4
0.1		03277260	Yonts Fork near Neon	12.4
	367.8		CARR FORK BASIN	85.5
0.2		03277450	Carr Fork near Sassafras	60.6
1.0	361	03277500	North Fork, Kentucky River, at Hazard	466
	317.7		TROUBLESOME CREEK BASIN	246
1.1		03278500	Troublesome Creek at Noble	177
2.0	304.5	03280000	North Fork, Kentucky River, at Jackson	1,101
	258.6		MIDDLE FORK, KENTUCKY RIVER, BASIN	559
2.1		03280600	Middle Fork, Kentucky River, near Hyden	202
2.2		03280700	Cutshin Creek at Wooton	61.3
2.3		03281000	Middle Fork, Kentucky River, at Tallega	537
	254.8		SOUTH FORK, KENTUCKY RIVER, BASIN	748
2.4		03281040	Red Bird River near Big Creek	155
2.5		03281100	Goose Creek at Manchester	163
2.6		03281500	South Fork, Kentucky River, at Booneville	722
3.0	249	03282000	Kentucky River at Lock 14 at Heidelberg	2,657
	190.8		RED RIVER BASIN	487
3.1		03282500	Red River near Hazel Green	65.8
3.2		03283200	Red River at Kentucky Highway 77 near Bowen	184
3.3		03283500	Red River at Clay City	362
4.0	176.4	03284000	Kentucky River at Lock 10 near Winchester	3,955
	150.3		SILVER CREEK BASIN	126
4.1		03284300	Silver Creek near Kingston	28.6
5.0	135.9	03284500	Kentucky River at Camp Nelson	4,425
	135.3		HICKMAN CREEK BASIN	101
5.1		03284550	West Hickman Creek at Jonestown	11.0
	118.2		DIX RIVER BASIN	442
5.2		03285000	Dix River near Danville	318
6.0	96.2	03287000	Kentucky River at Lock 6 near Salvisa	5,102
7.0	68.4	03287400	Kentucky River above Frankfort	5,292
8.0	65.8	03287500	Kentucky River at Lock 4 at Frankfort	5,411
9.0	56.0	03287570	Kentucky River below Frankfort	5,420
	51.9		ELKHORN CREEK BASIN	500
9.1		03288000	North Elkhorn Creek near Georgetown	119
9.2		03289000	South Elkhorn Creek at Fort Spring	24.0
9.3		03289300	South Elkhorn Creek near Midway	105
9.4		03289500	Elkhorn Creek near Frankfort	473
10.0	31.0	03290500	Kentucky River at Lock 2 at Lockport	6,180

Table 4.—Continued.				
Site Number	*Kentucky River Mile*	*Station Number*	*Station Name*	*Drainage Area (square miles)*
	11.0		EAGLE CREEK BASIN	519
10.1		03291500	Eagle Creek at Glencoe	437
Note: Kentucky River mile is at mouth of listed basin or at site on mainstem.				

Macroinvertebrates, small aquatic animals without backbones, are excellent indicators of intermediate to long-term changes (months to years) in water quality because of their relatively long and complex life histories. The number of macroinvertebrate types is often reduced in streams with poor water quality or limited habitat. In contrast, streams with exceptional water quality and diverse habitat generally support many macroinvertebrate types. Benthic macroinvertebrates, which live on stream bottoms, are useful in detecting alterations of aquatic environments. Streams with rocky beds (substrata) and well-oxygenated waters usually support communities dominated by aquatic insects such as mayflies, stoneflies, and caddisflies. A shift in dominance to more pollution-tolerant types such as midges and worms often occurs in response to increases in sedimentation or nutrient enrichment. Because they are essentially non-moving and have long life spans and specific living requirements, fresh-water mussels are very useful in determining long-term water-quality trends. Mussels in the Kentucky River Basin may be studied to determine the buildup of toxic substances such as heavy metals, pesticides, and other synthetic organic compounds.

Since fish may be able to swim away from locally polluted water, they are often less reliable as indicators of local water quality than macroinvertebrates and algae. However, the number and types of fish species can also indicate water quality. Clean-water streams support a variety of sensitive types, including game fish such as trout and muskellunge as well as non-game fish including certain darters and minnows. In contrast, fish communities in polluted water are frequently limited to pollution-tolerant species such as carp and mosquito fish. The analysis of fish tissue can also reveal important environmental information regarding the buildup of toxic substances, and the toxicity of waste water can be tested using species such as fathead minnows.

Brookfield and Porter's evaluation of aquatic life in the Kentucky River Basin was based on a number of sources. Data collected by R. R. Hannan, D. F. Harker, and others at the Kentucky Nature Preserves Commission, R. W. Logan and others at the Kentucky Division of Water, the Kentucky Department of Fish and Wildlife, and a large number of individuals from the University of Kentucky, Eastern Kentucky University, the University of Louisville, and other agencies and institutions in Kentucky were used. A summary of the findings is given below. In general, the information represents the period 1968--88. Where available, water-quality data are also included so that an overall picture of each stream or basin is obtained.

WATER QUALITY OF INDIVIDUAL BASINS AND STREAMS

North Fork of the Kentucky River Basin

Of the rivers draining the upper Kentucky River Basin, the North Fork of the Kentucky River (Fig. 2) seemed to be the most degraded in terms of water quality, sedimentation, and the capacity to support diverse aquatic life. In some areas high pollutant concentrations and sediment loads had eliminated all but the most pollution-tolerant species of aquatic life. Biological data for the North Fork of the Kentucky River mainstem were limited. Aquatic life in the river at Jackson indicated sediment and nutrient/organic enrichment. Water-quality data at Jackson reflected the effects of drainage from mining operations and discharge from domestic sewage treatment facilities. Williams (1975) documented nine species of fresh-water mussels in the North Fork, some probably represented by relic shells. The habitat for mussels had been reduced because of drastic environmental changes that had occurred in the past 50 to 75 years.

Sedimentation and high concentrations of iron and manganese were problems throughout the basin. On the mainstem of the North Fork, fecal coliform bacteria, lead, mercury, silver, and zinc affected water quality. Previous studies suggested that the few relatively natural watersheds in the North Fork Basin should be preserved. It is hoped that aquatic life from these streams will migrate into downstream areas once the impacts of land disturbance have declined.

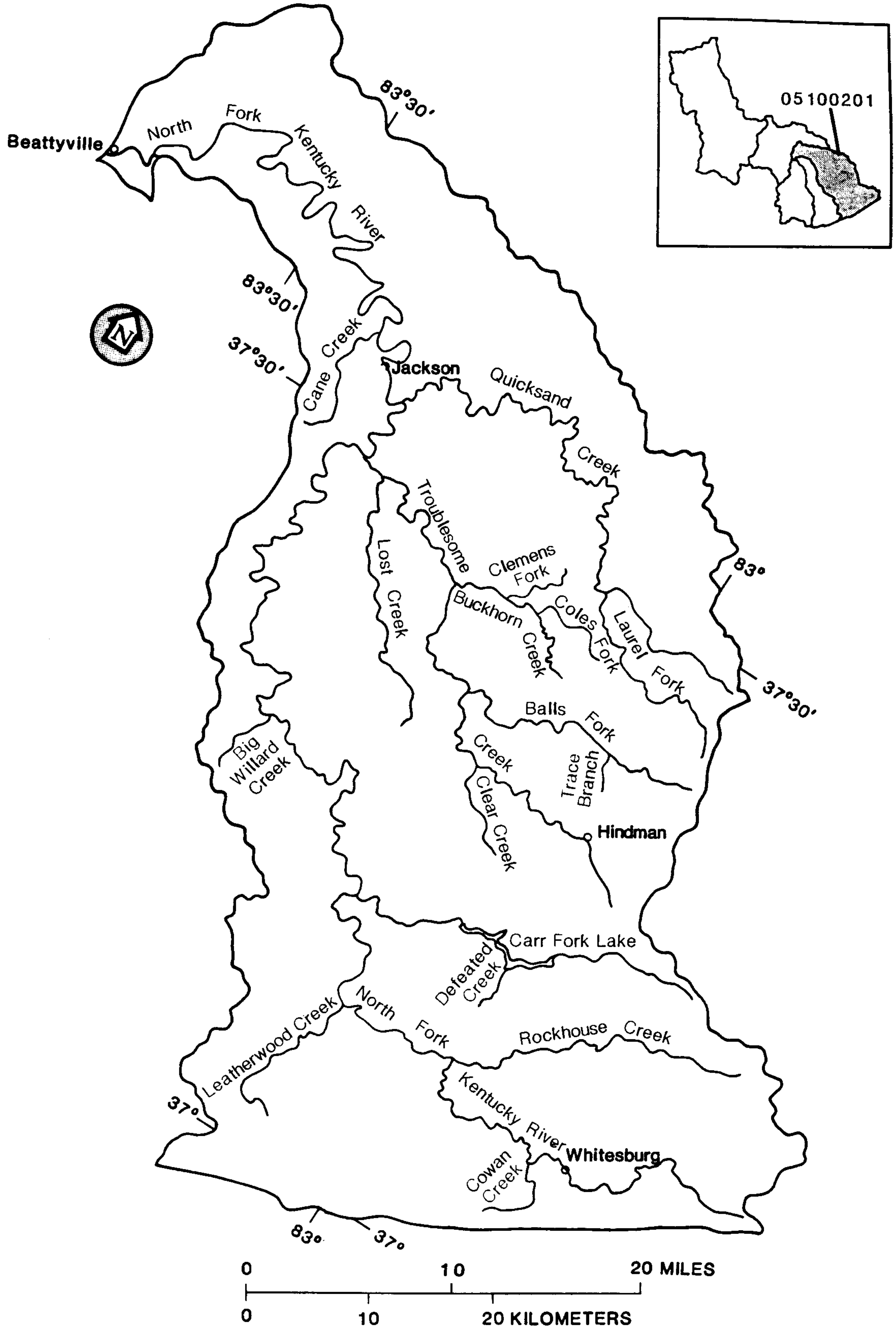

Figure 2. North Fork of the Kentucky River Basin. From Smoot and others (1990).

Water quality in the North Fork of the Kentucky River watershed was affected by iron, lead, manganese, mercury, silver, siltation, and fecal coliform bacteria. Data for the basin are given in Tables 5 and 6.

Buckhorn Creek Watershed

Buckhorn Creek supported numerous species of algae, benthic invertebrates, and fish, although elevated specific conductance and sulfate concentrations had been observed. Buckhorn Creek was deemed one of the largest relatively healthy aquatic systems in the Kentucky River Basin, and an important source for aquatic life that might someday recolonize Troublesome Creek and other river systems downstream. Buckhorn Creek, including Clemmons Fork and Coles Fork, was recommended as an Outstanding Resource Water by the Kentucky Nature Preserve Commission (KNPC, 1982).

Troublesome Creek Watershed

Troublesome Creek is the largest eastern tributary of the North Fork of the Kentucky River. Extensive contour and deep mining in the basin, a mountaintop removal project, and sewage eff luents from Hindman had severely degraded this stream. As late as 1973, some reaches near the mouth of Troublesome Creek and Balls Fork supported a viable fishery. Data collected in 1978 indicated that conditions had degraded throughout the Troublesome Creek drainage, as indicated by elevated pollutant concentrations. Benthic algae, macroinvertebrate, and fish populations were moderately diverse, but total numbers of organisms were low. Data for Troublesome Creek are given in Table 7.

Table 5.—Streams Not Fully Supporting Aquatic Life and Recreation in the North Fork of the Kentucky River Basin in 1990. From Kentucky Division of Water (1990).

Aquatic Life (miles)	*Cause*	*Source*	*Recreation (miles)*	*Cause*	*Source*
North Fork 8.6	siltation	mining/agriculture	46.1	pathogens	municipal/urban runoff
Lost Creek 18.5	siltation	mining			
Spring Fork, Quicksand Creek 15.0	siltation	mining			
South Fork, Quicksand Creek			13.8	pathogens	agriculture
Quicksand Creek			20.8	pathogens	agriculture
Rockhouse Creek 24.3	siltation	mining			

Table 6.—Water–Quality Parameters Exceeding Standards or Guidelines (Percent of Samples) in North Fork of the Kentucky River Basin. From Smoot and others (1990).

	Federal Guidelines		*Kentucky Standards*		
	Drinking Water	*Aquatic Life*	*Drinking Water*	*Aquatic Life*	*Recreation*
Yonts Fork near Neon					
Low pH	15	15		8	8
Total:					
Iron	77	54		54	
Manganese	100		100		

Table 6.—Continued.

	Federal Guidelines		*Kentucky Standards*		
	Drinking Water	*Aquatic Life*	*Drinking Water*	*Aquatic Life*	*Recreation*
North Fork near Hazard					
Total:					
Iron	100	72		72	
Manganese	94		94		
North Fork at Jackson					
Dissolved Solids	6				
Total:					
Cadmium		6			
Copper		6			
Iron	96	58		58	
Lead		50			
Manganese	94		94		
Mercury	5	100		30	
Silver		100			
Zinc		18		18	
Fecal Coliform			35		92

Carr Fork Watershed

Extensive strip, auger, and deep mining had occurred in the Carr Fork watershed, and Carr Fork Lake was noted to be undergoing accelerated sedimentation. Recreational uses were impaired because of water turbidity. Below the dam, Carr Fork was polluted by acid-mine drainage. Sedimentation seemed to pose the primary threat to aquatic life.

Laurel Fork Watershed

Laurel Fork appeared to be the only stream in the Quicksand Creek drainage not affected by sedimentation from mining operations. The stream was recommended as a "put and take"trout fishery and supported a "limited good quality" fishery for black bass and panfish in 1973. Investigations of aquatic life during 1978 revealed diverse, productive communities associated with good water quality and habitat diversity. Laurel Fork was recommended for consideration as a "refugium" to provide a source of aquatic life for recolonization of degraded downstream areas (Harker and others, 1979).

Middle Fork of the Kentucky River Basin

Primary land use in the basin (Fig. 3) includes coal mining, oil and gas production, forestry, and limited agriculture. These land-use practices affected many streams, but the effects on water quality and aquatic life did not appear to be as severe as in the North Fork Basin.

Algal blooms were observed in the headwater area of Buckhorn Lake and were probably the result of nutrient loads being discharged into the Middle Fork from the Hyden waste-water treatment plant. The river below Buckhorn Lake benefitted from low-flow augmentation and reduced sediment loads. The section of the river below Buckhorn Dam to the mouth was recommended as an Outstanding Resource Water (KNPC, 1982).

The water quality in the Middle Fork watershed was affected by iron, lead, manganese, mercury, siltation, oil and grease, and fecal coliform bacteria. Data for the Middle Fork of the Kentucky River are given in Tables 8 and 9.

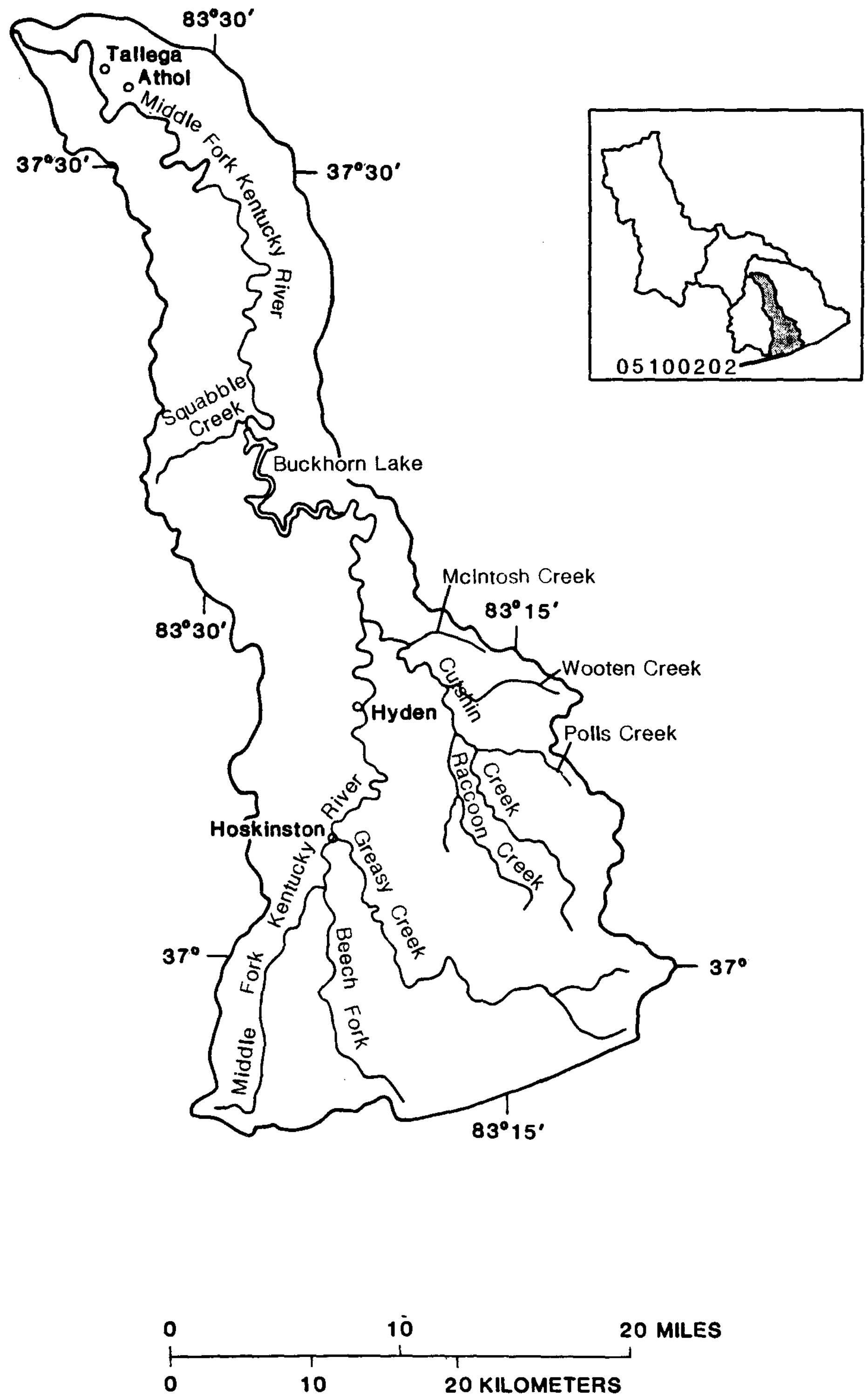

Figure 3. Middle Fork of the Kentucky River Basin. From Smoot and others (1990).

Table 7.—Streams Not Fully Supporting Aquatic Life and Recreation in the Troublesome Creek Watershed in 1990. From Kentucky Division of Water (1990).

Aquatic Life (miles)	*Cause*	*Source*	*Recreation (miles)*	*Cause*	*Source*
Troublesome Creek			49.5	pathogens	municipal/ septic tanks

Table 8.—Streams Not Fully Supporting Aquatic Life and Recreation in the Middle Fork of the Kentucky River Basin in 1990. From Kentucky Division of Water (1990).

Aquatic Life (miles)	*Cause*	*Source*	*Recreation (miles)*	*Cause*	*Source*
Middle Fork, Kentucky River			43.2	pathogens	agriculture

Table 9.—Water-Quality Parameters Exceeding Standards or Guidelines (Percent of Samples) in Middle Fork of the Kentucky River Basin. From Smoot and others (1990).

	Federal Guidelines		*Kentucky Standards*		
	Drinking Water	*Aquatic Life*	*Drinking Water*	*Aquatic Life*	*Recreation*
Middle Fork near Hyden					
Alkalinity		19			
Total:					
Iron	100	52		52	
Manganese	86		86		
Middle Fork at Tallega					
Low pH	8	8			
Alkalinity		12			
Total:					
Cadmium		11			
Copper		6			
Iron	92	47		47	
Lead		49			
Manganese	96		96		
Mercury		100		14	
Zinc		15		15	
Fecal Coliform			4		24

Greasy Creek Watershed

Greasy Creek flows from Harlan County to join the Middle Fork near Hoskinston. Biological investigations revealed diverse, productive aquatic communities during the late 1970's. In 1979 Greasy Creek was cited by Harker and others (1979) as supporting one of the most diverse fish populations in the Kentucky River Basin. Greasy Creek was considered an important source for recolonization of downstream areas adversely affected by land-use activities, and was recommended as an Outstanding Resource Water (KNPC, 1982) to provide a muskellunge habitat for spawning and a smallmouth and rock bass habitat and fishery. There are indications that the water quality of Greasy Creek has deteriorated since those studies were performed.

Cutshin Creek Watershed

Cutshin Creek, the largest tributary to the Middle Fork, flows from southeastern Leslie County and joins Middle Fork north of Hyden. Cutshin Creek was a source of sediment and had poor water quality. Elevated concentrations of sulfate, magnesium, sodium, and calcium were observed during low flows in 1978. The creek was the site of recurring fish kills caused by oil drilling and mining operations during the early to mid-1 980's.

in spite of the apparently poor water quality, biological studies indicated diverse aquatic communities. These studies were characterized, however, by types thatwere tolerant to awide range of environmental factors.

Data for the Cutshin Creek watershed are given in Tables 10 and 11.

Squabble Creek Watershed

Squabble Creek flows from western Perry County and joins the Middle Fork about 4 miles below Buckhorn Dam. Because of its location, this creek was sidered an important source of aquatic life to the Middle Fork downstream of Buckhorn Lake. In 1979 Squabble Creek was affected by drainage from old strip mines and discharges from two small sewage treatment plants. Water from Squabble Creek had high concentrations of constituents associated with mining, such as sulfates. The effects of sewage effluent were indicated by high nutrient concentrations. Flocculent masses and iron ochre seeps were also observed. Biological investigations of Squabble Creek indicated environmental stresses caused by poor water quality or reduced habitat. Algae were typified by numerous pollution-tolerant species. Siltation and stream channelization were the primary factors affecting the macroinvertebrates at the sampled site. Impacts to fish populations were difficult to evaluate at the sampling site because of its proximity to the Middle Fork. Squabble Creek provided spawning and feeding sites for many migratory fish that were effectively blocked from upstream reaches by Buckhorn Dam.

South Fork of the Kentucky River Basin

The South Fork mainstern begins at the confluence of Goose Creek and Red Bird River and flows about 40 miles to the Kentucky River at Beattyville (Fig. 4). The richness and diversity of small aquatic animal life decreases downstream, indicating a compounding of environmental effects as tributaries with poor water quality and large sediment loads join the mainstem. Macroinvertebrate samples were dominated by pollutiontolerant species. The sampling site at Booneville was affected by sedimentation from land disturbance and nutrient enrichment from numerous sewage treatment effluent discharges. Because the South Fork still provided some muskellunge habitat, it was recommended as an Outstanding Resource Water by the Kentucky Nature Preserves Commission (1982).

Table 10.—Streams Not Fully Supporting Aquatic Life and Recreation in the Cutshin Creek Watershed in 1990. From Kentucky Division of Water (1990).

Aquatic Life (miles)	*Cause*	*Source*	*Recreation (miles)*	*Cause*	*Source*
Cutshin Creek 28.8	oil and grease/siltation	petroleum/mining			
Raccoon Creek 8.5	oil and grease/siltation	petroleum/mining			

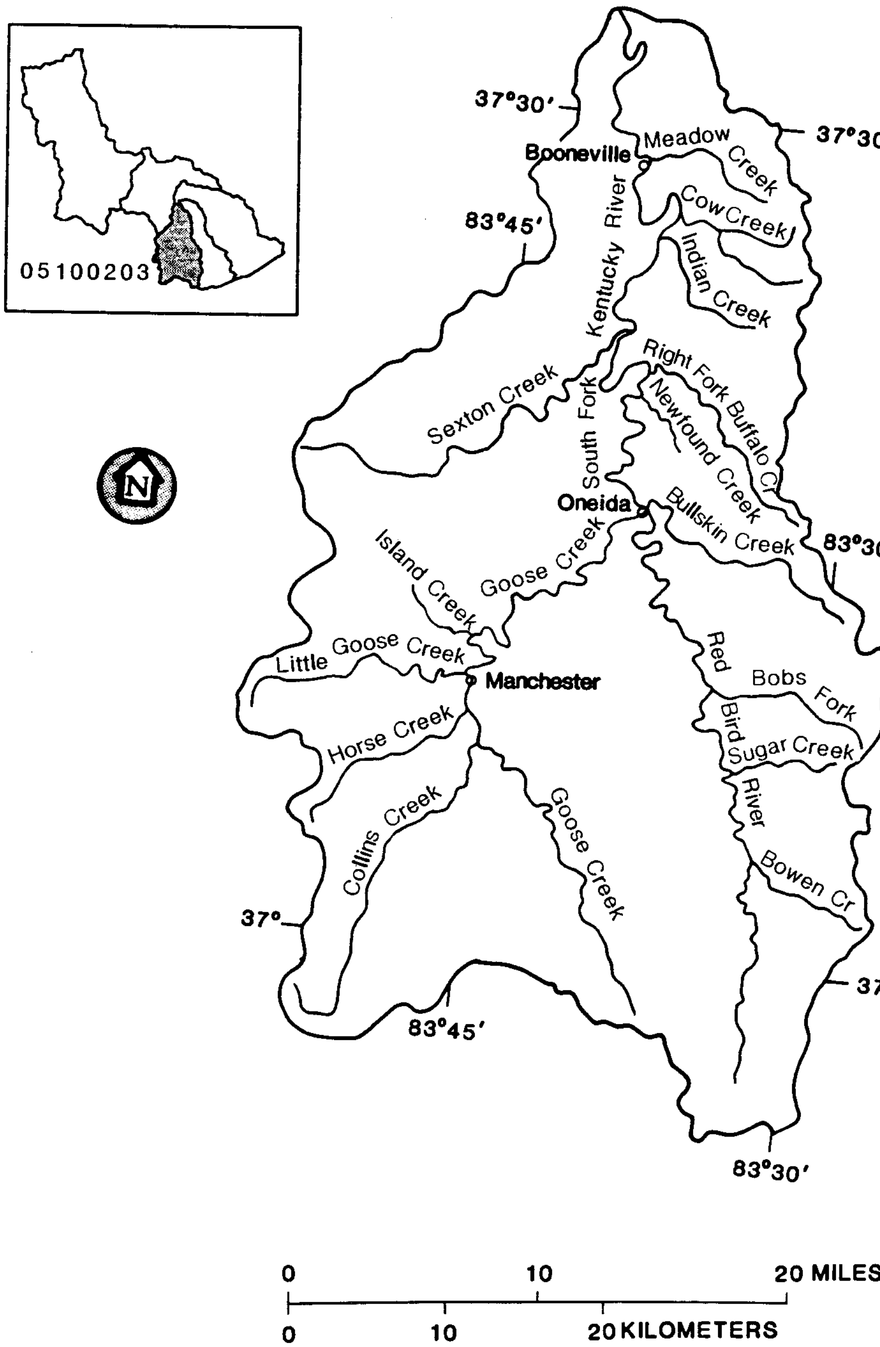

Figure 4. South Fork of the Kentucky River Basin. From Smoot and others (1990).

Table 11.—Water–Quality Parameters Exceeding Standards or Guidelines (Percent of Samples) in Cutshin Creek Watershed. From Smoot and others (1990).

	Federal Guidelines		*Kentucky Standards*		
	Drinking Water	*Aquatic Life*	*Drinking Water*	*Aquatic Life*	*Recreation*
Cutshin Creek at Wooton					
Alkalinity		10			

Table 12.—Water–Quality Parameters Exceeding Standards or Guidelines (Percent of Samples) in South Fork of the Kentucky River Basin. From Smoot and others (1990).

	Federal Guidelines		*Kentucky Standards*		
	Drinking Water	*Aquatic Life*	*Drinking Water*	*Aquatic Life*	*Recreation*
South Fork at Booneville					
Low pH	5	5			
Alkalinity		12			
Total:					
Cadmium		11			
Copper		6			
Iron	87	28		28	
Lead		60	3		
Manganese	92		92		
Mercury	3	100		17	
Silver		67			
Zinc		12		12	
Fecal Coliform					40

Iron, lead, manganese, mercury, silver, and fecal coliform bacteria impaired the water quality of the basin. Data for the South Fork of the Kentucky River are given in Table 12.

Goose Creek Watershed

Goose Creek begins in Clay County and joins the Red Bird River at Oneida to form the South Fork. The upper reaches of Goose Creek seemed to have good water quality and supported diverse aquatic life. The lower half of Goose Creek was affected by acid-mine drainage and sediment from Horse Creek and Little Goose Creek. Collins Fork, a tributary, was found in 1973 to be relatively unaffected, and provided cold water and long, deep pools for smallmouth bass, rock bass, and muskellunge.

Several fish kills attributable to coal-mining discharges occurred at Goose Creek from 1969 to 1973. Water quality improved afterwards, although the eff ects of siltation were still apparent.

The Goose Creek drainage was considered to be a source of small aquatic animals for recolonization and provided some of the last muskellunge habitat in the basin. Goose Creek and Collins Fork were identified as Sport Fishery Resources by the Department of Fish and Wildlife, and were recommended as Outstanding Resource Waters (KNPC, 1982). Protection from the effects of rnining operations and from the discharge of treated sewage from Manchester are necessary to maintain good water quality in the Goose Creek Basin.

Data for Goose Creek at Manchester are given in Table 13.

Table 13.—Water–Quality Parameters Exceeding Standards or Guidelines (Percent of Samples) in the Goose Creek Watershed. From Smoot and others (1990).

	Federal Guidelines		*Kentucky Standards*		
	Drinking Water	*Aquatic Life*	*Drinking Water*	*Aquatic Life*	*Recreation*
Goose Creek at Manchester					
Alkalinity		37			
Total:					
Iron	100	84		84	
Manganese	100		100		

Red Bird River Basin

The Red Bird River is the largest tributary of the South Fork, draining the eastern portion of the upper basin. Biological investigations indicated some effects from sediment in the headwater area, but the biological quality improved in downstream reaches. In the early 1970's fishing was considered good from the mouth upstream to Sugar Creek. Abundant fish food in the form of benthic invertebrates was noted in the river. This stream, from the confluence of Sugar Creek to the mouth, was designated a Sport Fishery Resource and recommended as an Outstanding Resource Water (KNPC, 1982).

Sexton Creek Watershed

Sexton Creek flows from the west and joins South Fork about halfway between Oneida and Booneville. Fish kills caused by coal-mining discharge were reported in the 1970's. At least in the lower reaches, the effects of mining on stream quality were reduced during the 1980's because Sexton Creek was reported to have one of the highest densities of muskellunge of all South Fork streams. Because it is a valuable habitat for muskellunge and golden redhorse, Sexton Creek was recommended as an Outstanding Resource Water by the Kentucky Nature Preserves Commission (1982).

Buck Creek Watershed

Buck Creek begins in Owsley County and flows northeast to join the South Fork near Booneville. Concentrations of sulfate and magnesium in the creek were higher than in undisturbed streams in the area in 1979; otherwise, reasonably good water quality was indicated. Macroinvertebrate data indicated good water quality and adequate habitat. Fish from the creek were typical for most eastern Kentucky drainages. Arrow darters, which were listed as being of special concern, were collected from Buck Creek. Extreme turbidity was present following a rainstorm at the time of sampling, indicating that sedimentation from surface mines or agricultural lands could pose a threat to aquatic resources.

Kentucky River Basin from South Fork to Red River

This area of the Kentucky River Basin lies in the Knobs region (Fig. 5). Brines from oil and gas operations and sedimentation from mining affected aquatic life in the basin. Pollution from agricultural sources was more of a problem here than in the Eastern Kentucky Coal Field. Sewage effluents contributed by the major urban centers also tended to have more detrimental effects on water quality in this area because of low velocity.

Biological communities in the Kentucky River at Heidelberg have been routinely sampled by the Kentucky Division of Water. Blue-green algal blooms were reported upstream from Lock 14, and attached algal biomass and standing crop were elevated. This occurrence was partially attributed to waste-water effluent at Beattyville and the impounded nature of the river. Evaluation of benthic diatoms collected since 1978 indicates that the effects of oil and gas operations may have been most pronounced during the early to mid 1980's. Collections in 1985-86 contained fewer halophilic (salt-loving) species, indicating a reduction in the amount of brines reaching the stream. Sedimentation from upstream land disturbance had reduced benthic macroinvertebrate habitat at this slow-moving, deepwater site. Historically, the river supported viable mussel populations, but no mussel beds were observed in the Lock 14 pool in 1975.

The fish of the Lock 14 pool were typical of a large river; the pool supported a sport fishery as well as a limited commercial fishery. Thirteen species of fish were reported in the Lock 14 pool in 1975, compared with 20

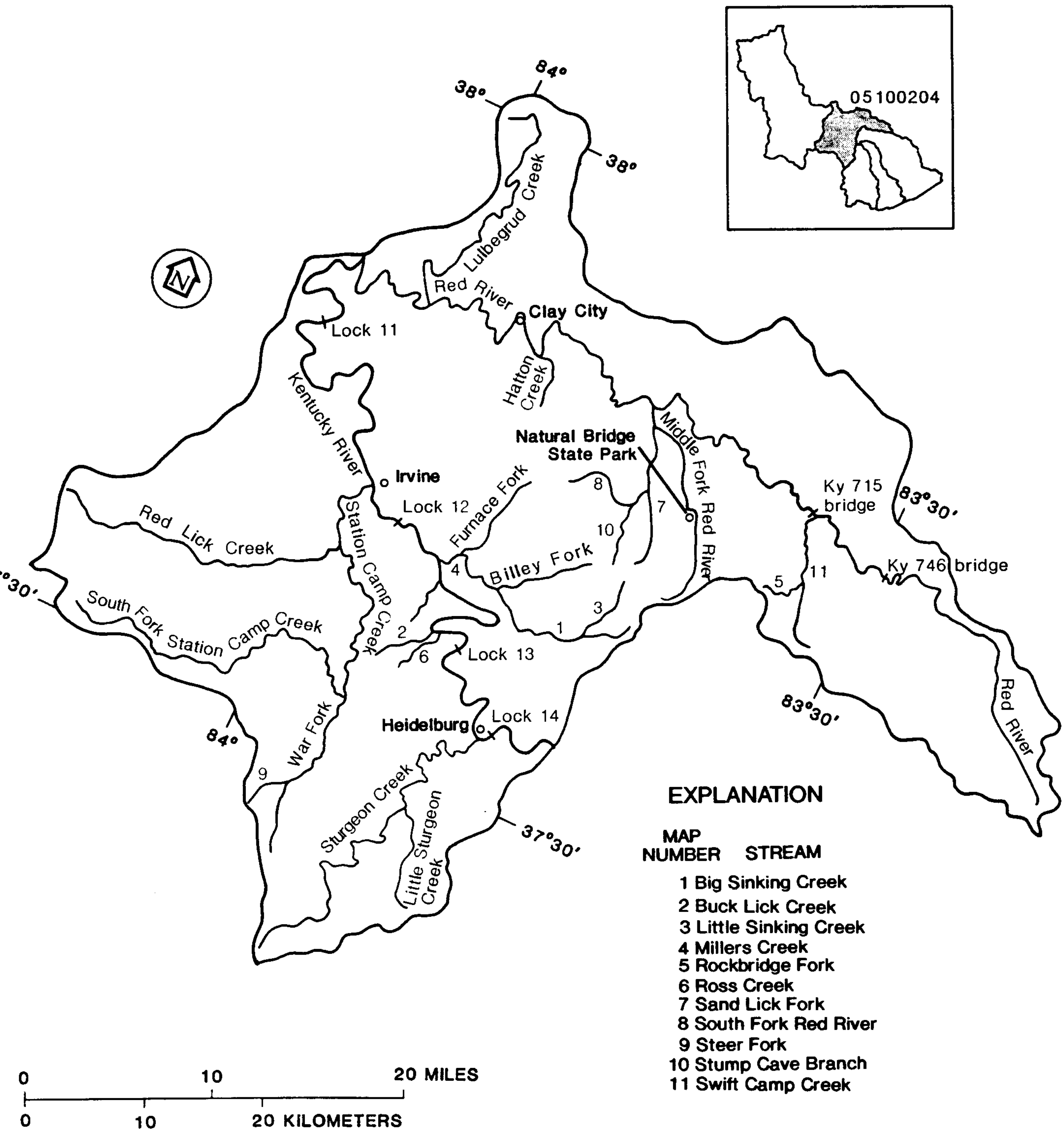

Figure 5. Basin of the Kentucky River from the South Fork to the Red River. From Smoot and others (1990).

to 22 species in Pools 11 to 13, possibly reflecting large sediment loads that were deposited upstream from Dam 14. Paddlefish were only observed at Pool I I during 1973. This occurrence apparently was one of the last published records of this unique species in the Kentucky River Basin. Although no mussels were observed in 1975 in Pool 14, four species were collected from Pools 11 and 13 and six species from Pool 12. None of these mussels beds were considered commercially valuable. Detectible levels of chlordane, aldrin, dieldrin, and several heavy metals were found in fish tissue samples in 1979-81. Bioassay studies revealed acute toxicity to fathead minnows during the fall of 1986 and the spring and winter of 1987 at this site.

Iron, lead, manganese, mercury, silver, chlorides, and fecal coliform bacteria affected the water quality in this part of the Kentucky River Basin. Data for the Kentucky River at Heidelberg are given in Tables 14 and 15.

Sturgeon Creek Watershed

Sturgeon Creek flows from eastern Jackson County and joins the Kentucky River immediately below Lock 14. Although mining in the basin posed a potential threat to aquatic life, available data indicate that Sturgeon Creek has been a high-quality stream. This assessment was based on the occurrence of sensitive diatom species, diverse macroinvertebrate communities, and a large number of fish species. Because several fish species collected from Sturgeon Creek were listed as being of special concern, it was recommended by both the Kentucky Department of Fish and Wildlife Resources and the Kentucky Nature Preserves Commission (1982) for designation as an Outstanding Resource Water.

Table 14.—Streams Not Fully Supporting Aquatic Life and Recreation in the Kentucky River Basin from South Fork to Red River in 1990. From Kentucky Division of Water (1990).

Aquatic Life (miles)	*Cause*	*Source*	*Recreation (miles)*	*Cause*	*Source*
Kentucky River at Heidelberg			28.3	pathogens	municipal/ agriculture

Table 15.—Water–Quality Parameters Exceeding Standards or Guidelines (Percent of Samples) in the Kentucky River Basin from South Fork to Red River. From Smoot and others (1990).

	Federal Guidelines		*Kentucky Standards*		
	Drinking Water	*Aquatic Life*	*Drinking Water*	*Aquatic Life*	*Recreation*
Kentucky River at Heidelberg					
Low pH	1	1			
High pH	1				
Dissolved Solids	1				
Total:					
Nitrogen				1	
Arsenic	1			1	
Cadmium	2	19		2	
Copper		16			
Iron	80	30		30	
Lead	9	70	9		
Manganese	94		94		
Mercury	10	100		56	
Silver		80			
Zinc		20		20	
Fecal Coliform			3		49

Millers Creek and Ross Creek Watersheds

These creeks, which flow into Pool 12 from the north and south, respectively, were the subject of biological studies during the early 1980's as a result of environmental concerns regarding brine discharges from oil and gas operations. Streams in both basins had elevated specific conductance and concentrations of chloride and barium.

Biological surveys were conducted in the Millers Creek Basin by the Kentucky Department of Water, which found most streams to be moderately to severely affected by brines from oil and gas operations. Halophilic (tolerant to brines) and epipelic (associated with sediment) species were common. Headwater areas of Big Sinking Creek, Little Sinking Creek, Billey Fork, and Furnace Fork supported low densities of macroinvertebrate organisms. Fish communities were severely affected by brines, and most streams supported fewer than 10 tolerant species. Two sampling sites on Big and Little Sinking Creeks were apparently devoid of fish. Small, unaffected tributaries to Big Sinking Creek contained diverse, productive aquatic communities. Chloride concentrations in the lower reaches of Millers Creek exceeded 1,000 mg/L (milligrams per liter). Background concentrations of chloride in unaffected streams were typically less than 10 mg/L. It is apparent that high concentrations of constituents of brine-water discharges in this area were toxic to many indigenous aquatic organisms. The vegetation and aquatic life of Buck Lick Creek, and Ross Creek below the confluence with Buck Lick Creek, were also severely degraded by brine. Algal and macroinvertebrate communities were limited to types tolerant to elevated salinity. Fish were eliminated in Buck Creek, and reduced numbers and varieties were noted in Ross Creek below Buck Lick Creek.

Data for the Millers Creek watershed are given in Table 16.

Station Camp Creek Watershed

Station Camp Creek is formed by the confluence of War Fork and South Fork in Jackson County. It then flows northwest to join the Kentucky River at Irvine. Based on published interpretations of available biological data, Station Camp Creek can be considered to be one of the largest high-quality watersheds in the Kentucky River Basin. Fifty-five fish species have been identified in the basin, including a sizeable muskellunge population. Station Camp Creek, including War Fork and South Fork, were recommended as Outstanding Resource Waters (KNPC, 1982).

Red River Basin

Because of their unique aquatic environments, streams in the Red River Basin have been the subject of numerous biological investigations.

The Red River from Kentucky Highway 746 to Kentucky Highway 715 has been designated as a Kentucky Wild River (Miller, Wihry, and Lee, Inc., 1980). The remaining sections provide habitat for muskellunge and were recommended as Outstanding Resource Waters (KNPC, 1982). Swift Camp Creek, a high-quality tributary, was also recommended as an Outstanding Resource Water.

Above the confluence with the Middle Fork of the Red River the algal flora of the Red River is perhaps the most diverse in the Kentucky River Basin. The diatom and macroinvertebrate communities indicated excellent water quality during the late 1970's. Fifteen species of fresh-water mussels were reported from the Wild River section. Eighty-five species of fish were identified in the basin.

Increases in epipelic (associated with sediments) diatoms were observed during the mid 1980's. The entire mussel community seemed to have been eliminated by the effects of sedimentation during the early 1980's, although collections in 1988 revealed 19 species in the Wild River section and downstream. A reduction of fish species, particularly darters, was observed in 1985, and was attributed to loss of habitat from sedimentation.

Analyses of biological communities in the Hazel Green reach have generally indicated good water quality and habitat availability. However, bioassay studies revealed acute toxicity to fathead minnows in the Red River near Hazel Green, particularly during the fall of 1986. Detectible levels of dieldrin, DDT, chlordane, and heavy metals were measured in fish tissue samples. Some toxicity to fathead minnows was documented during 1986-87 at Clay City.

Table 16.—Streams Not Fully Supporting Aquatic Life and Recreation in the Millers Creek and Ross Creek Watersheds in 1990. From Kentucky Division of Water (1990).

Aquatic Life (miles)	*Cause*	*Source*	*Recreation (miles)*	*Cause*	*Source*
Millers Creek 6.4	chlorides	oil and gas			
Big Sinking Creek 14.1	chlorides	oil and gas			
Billey Fork 8.6	chlorides	oil and gas			

Biological data on downstream reaches of the Red River near Clay City indicate fairly good water quality, although somewhat elevated chloride concentrations were reported.

Hatton and Lulbegrud Creeks, which join the Red River near Clay City, were both characterized by good water quality and diverse biological communities.

Water quality in the Red River Basin has been affected by siltation, iron, lead, manganese, mercury, silver, chlorides, and fecal coliform bacteria. Data on the Red River are given in Tables 17 and 18.

Middle and South Forks of the Red River

Biological and water-quality investigations indicated that the Middle and South Forks of the Red River were affected by oil and gas production and coal mining. Extremely high concentrations of chloride (1,500-10,000 mg/L) and specific conductance values (4,500-27,000 gS/cm [microsiemens/centimeter]) were reported. The poor water quality affected the biological communities at virtually all sampling sites in this part of the basin. Algal communities were dominated by halophilic species. Fish in the Middle and South Forks were also severely affected by brine. No fish were found at the Sand Lick Creek and Stump Cave Branch sites.

Data on the Middle and South Forks of the Red River are given in Table 19.

Kentucky River Basin from Red River to Ohio River

On the mainstem Kentucky River (Fig. 6) the availability of biological data was primarily limited to Pools 2 (Lockport), 3 (Frankfort), and 7 (Camp Nelson). Historical fishery and fresh-water mussel information was available from other pools. Seventeen to 22 fish species were reported at Pools 5 through 10, 15 at Pool 3. and 10 at Pools I and 2. Most pools supported 10 to 15 species of fresh-water mussels, with fewer species at Pools 2, 3, and 6 (reported in 1975). Beds in Pools 3, 5, and 8 were considered commercially valuable.

Phytoplankton communities at Camp Nelson were dominated by types associated with nutrient enrichment. Localized sources of nutrient enrichment included Hickman Creek, which received treated waste water from parts of Lexington, and other waste-water discharges and nutrients from agricultural sources. Fish tissues revealed detectible concentrations of chlordane and heavy metals. Sources were thought to be housing construction and light industry in the Lexington area. Bioassays revealed acute toxicity to fathead minnows, particularly during the fall of 1986 and the summer of 1987. Bioassays of waste-water effluents from the West Hickman (Lexington) treatment plant revealed toxicity in the final effluent and in the receiving stream of West Hickman Creek.

Phytoplankton communities near Frankfort were dominated by diatoms associated with nutrient enrichment. Analyses of fish tissues indicated detectible levels of chlordane, aldrin, dieldrin, DDT, and heavy metals. Chlordane levels exceeded Food and Drug Administration action levels during 1984. Acute toxicity to fathead minnows during 1986-87 was reported. Bioassays on the discharge from the Frankfort waste-water treatment plant in the summer of 1985 revealed no acute toxicity in the effluent.

Algal communities at Lock 2 were reported to be similar to those in Frankfort.

Water quality in this region of the Kentucky River Basin was affected by cadmium, copper, iron, lead, manganese, mercury, silver, zinc, organic enrichment, nutrients, fecal coliform bacteria, and unknown toxins. Data on the Kentucky River Basin from the Red River to the Ohio River are given in Tables 20 and 21.

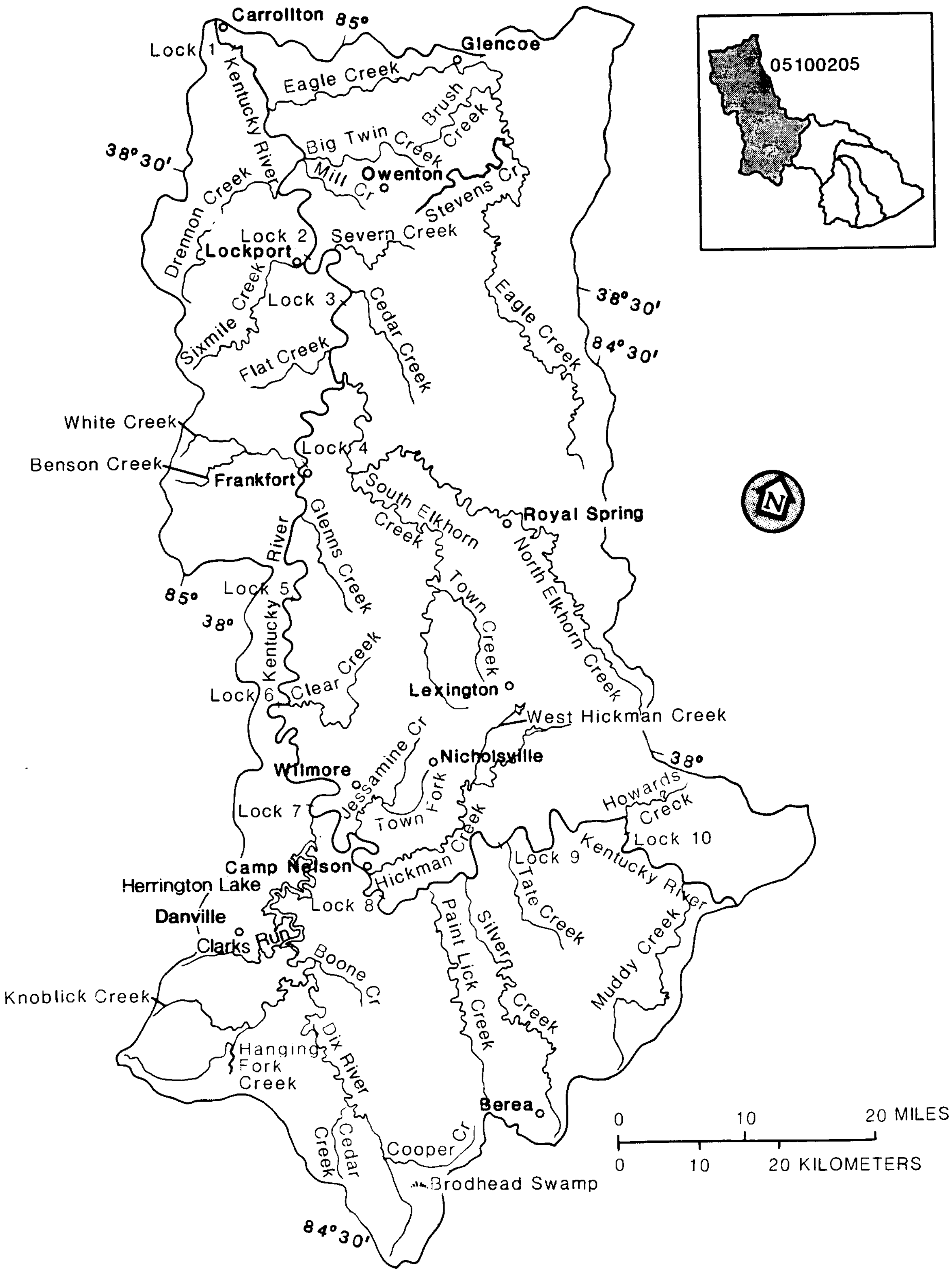

Figure 6. Basin of the Kentucky River from the Red River to the Ohio River. From Smoot and others (1990).

Table 17.—Streams Not Fully Supporting Aquatic Life and Recreation in the Red River Basin in 1990. From Kentucky Division of Water (1990).

Aquatic Life (miles)	*Cause*	*Source*	*Recreation (miles)*	*Cause*	*Source*
Red River 34.3	siltation/metals	habitat damage/ mining	10.1	pathogens	municipal

Table 18.—Water-Quality Parameters Exceeding Standards or Guidelines (Percent of Samples) in the Red River Basin from South Fork to Red River. From Smoot and others (1990).

	Federal Guidelines		*Kentucky Standards*		
	Drinking Water	*Aquatic Life*	*Drinking Water*	*Aquatic Life*	*Recreation*
Red River near Hazel Green					
Low pH	5	5			
Alkalinity		28			
Total:					
Cadmium	3	26		3	
Chromium	1		1		
Copper		11			
Iron	94	35		35	
Lead	7	58	7		
Manganese	99		99		
Mercury	4	100		54	
Silver		100			
Zinc		3		3	
Fecal Coliform			7		66
Red River near Bowen					
High pH	2	2		2	2

Table 19.—Streams Not Fully Supporting Aquatic Life and Recreation in the Middle and South Forks of the Red River in 1990. From Kentucky Division of Water (1990).

Aquatic Life (miles)	*Cause*	*Source*	*Recreation (miles)*	*Cause*	*Source*
South Fork, Red River 11.8	chlorides	oil and gas			
Sand Lick Fork 5.0	chlorides	oil and gas			

Table 20.—Streams Not Fully Supporting Aquatic Life and Recreation in the Kentucky River Basin from Red River to the Ohio River in 1990.

Aquatic Life (miles)	*Cause*	*Source*	*Recreation (miles)*	*Cause*	*Source*
Kentucky River at Camp Nelson			37.7	pathogens	unknown
Kentucky River at Frankfort			30.1	pathogens	unknown
Walnut Meadow Branch 3.6	organic enrichment/nutrients	municipal			
Brushy Fork 0.2	nutrients	municipal			

Silver Creek Watershed

Silver Creek flows northward from near Berea to join the Kentucky River in Pool 8. The stream was "one of the best streams in the drainage, supporting a good sport fishery for black and rock bass" in 1973 (Jones, 1973). Because of chronic pollution from the discharge of treated domestic waste water at Berea, an intensive investigation was conducted by the Kentucky Division of Water in 1982. Water-quality violations were observed for undissociated hydrogen sulfide, phthalate esters, aluminum, mercury, and fecal coliform bacteria. Algae were dominated by types associated with nutrient enrichment and high pollution tolerance. Biological communities had partially recovered in downstream reaches, but nutrient enrichment from agricultural runoff was indicated by dense growths of filamentous algae. Abundant macroinvertebrate habitat and good water quality were indicated in Silver Creek just upstream of its confluence with the Kentucky River, however. This part of Silver Creek provided a habitat for smallmouth bass, was designated as a Sport Fishery Resource, and was recommended as an Outstanding Resource Water (KNPC, 1982).

Data for Silver Creek are given in Table 22.

Jessamine Creek Watershed

The creek flows southward from north-central Jessamine County through one of the most scenic gorges in the Inner Blue Grass to join the Kentucky River near Wilmore. This stream was classified as an Outstanding Resource Water (KNPC, 1982) because of the presence of three protected species of bats. Fish species reported include bass and bluegill. Bioassays conducted by the Kentucky Division of Water indicated acute toxicity to fathead minnows in the Nicholasville and Wilmore sewage effluents in Town Branch downstream from the Wilmore waste-water treatment plant.

Dix River Basin

The Dix River flows from Rockcastle County north about 85 miles and joins the Kentucky River upstream of Lock and Dam 7. The upper parts of the Dix and Copper Creek were affected by agricultural activities (organic matter and heavy use of the stream by cattle). Biological communities were dominated by species tolerant of a wide range of water-quality conditions. Hanging Fork Creek contained more sensitive species. Clarks Run received waste water and other point discharges from Danville, and was adversely affected. Acute toxicity to fathead Minnows was documented in 1986-87. Water quality in the Dix River below Herrington Lake Dam was enhanced by the mitigating effects of the lake. Cooler, less turbid waters were released to the Kentucky River during summer. The Dix River below the dam was identified as an important sport fishery resource by the Kentucky Department of Fish and Wildlife Resources, and was recommended as an Outstanding Resource Water (KNPC, 1982).

Data for the Dix River Basin are given in Table 23.

Elkhorn Creek Watershed

North Elkhorn Creek flows from northern Fayette County through Scott and Woodford Counties and merges with South Elkhorn Creek in Franklin County to form Elkhorn Creek. Elkhorn Creek joins the Kentucky River about 10 miles north of Frankfort in Pool 3.

Table 21.—Water–Quality Parameters Exceeding Standards or Guidelines (Percent of Samples) in the Kentucky River Basin from Red River to the Ohio River. From Smoot and others (1990).

	Federal Guidelines		*Kentucky Standards*		
	Drinking Water	*Aquatic Life*	*Drinking Water*	*Aquatic Life*	*Recreation*
Kentucky River at Camp Nelson					
High pH	1				
Dissolved Solids	2				
Total:					
Cadmium	10	25		8	
Copper		8			
Iron	59	28		28	
Lead	12	81	12		
Manganese	76		76		
Mercury	9	100		50	
Silver		100			
Zinc		8		8	
Fecal Coliform			6		23
Kentucky River above Frankfort					
Low pH	1	1			
High pH	1				
Alkalinity		1			
Total:					
Cadmium	11	28		10	
Copper		21			
Iron	57	25		25	
Lead	13	68	13		
Manganese	56		56		
Mercury	10	100		64	
Silver		100			
Zinc		14		14	
Fecal Coliform					22
Kentucky River below Frankfort					
Low pH	1	1		1	1
High pH	3				
Total:					
Nitrogen				1	
Cadmium	14	33		14	
Copper		8			
Iron	59	25		25	
Lead	22	73	22		
Manganese	64		64		
Mercury	7	100		64	
Silver		100			
Zinc		9		9	
Fecal Coliform			2		36

Table 21.—Continued.

	Federal Guidelines		*Kentucky Standards*		
	Drinking Water	*Aquatic Life*	*Drinking Water*	*Aquatic Life*	*Recreation*
Kentucky River at Lockport					
Low pH	3	3			
High pH	1				
Total:					
Arsenic	1			1	
Copper		46			
Iron	96	52		52	
Lead		96			
Manganese	96		96		
Mercury		100		60	
Silver		9			
Zinc		37		37	
Fecal Coliform			17		75

North Elkhorn Creek is an extremely popular recreational resource and was recommended as an Outstanding Resource Water (KNPC, 1982) because of Viable populations of several organisms, including freshwater mussels. Because it provided habitat for smallmouth bass, it was also designated as a Sport Fishery Resource. Biological monitoring of the creek and its major tributaries by the Kentucky Division of Water was in progress in 1989, paying particular attention to the potential effects of industrial discharges on water quality. Sewage effluent into the creek from the Georgetown waste-water treatment plant was toxic to fathead minnows in May of 1986. Acute toxicity was also observed in the stream above and below the discharge point.

Data for the North Elkhorn Creek watershed are given in Table 24.

South Elkhorn Creek Watershed

South Elkhorn Creek was severely degraded by sewage effluent discharged into Town Branch by the city of Lexington from 1970 to 1986. Although both the North and South Elkhorn drain areas of similar geology, the aquatic life supported by South Elkhorn Creek differed from that of North Elkhorn Creek.

Benthic invertebrate collections from South Elkhorn Creek below Town Branch in 1968-69 were composed primarily of Tubifex worms, which are characteristic of grossly polluted streams. Fish populations below Town Branch were severely affected by low dissolved oxygen content.

Water-quality and biological investigations were conducted at seven locations during 1981. Results indicated degraded environmental conditions throughout the system. Biological data collected from 1984 to 1986 were similar to the 1981 data. Macroinvertebrates on artificial substrates were limited to one pollution-tolerant species, indicating toxicity to most species of macroinvertebrates. Bioassays indicated consistent toxicity to fathead minnows, particularly during the summer of 1987.

Table 22.—Streams Not Fully Supporting Aquatic Life and Recreation in the Silver Creek Watershed in 1990. From Kentucky Division of Water (1990).

Aquatic Life (miles)	*Cause*	*Source*	*Recreation (miles)*	*Cause*	*Source*
Silver Creek 2.0	organic enrichment/nutrients	municipal			

Table 23.—Streams Not Fully Supporting Aquatic Life and Recreation in the Dix River Basin in 1990. From Kentucky Division of Water (1990).

Aquatic Life (miles)	*Cause*	*Source*	*Recreation (miles)*	*Cause*	*Source*
Dix River			13.5	pathogens	municipal
Clarks Run 8.0	organic enrichment/unknown toxicity	municipal			

Table 24.—Streams Not Fully Supporting Aquatic Life and Recreation in the Elkhorn Creek Watershed in 1990. From Kentucky Division of Water (1990).

Aquatic Life (miles)	*Cause*	*Source*	*Recreation (miles)*	*Cause*	*Source*
North Elkhorn 2.0	organic enrichment/chlorine/nutrients	municipal			
Cane Run 17.4	unknown toxicity	unknown			

Data for the South Elkhorn Creek watershed are given in Tables 25 and 26.

Eagle Creek Watershed

Eagle Creek is the last major tributary to join the Kentucky River. Eagle Creek was recommended for inclusion as an Outstanding Resource Water by the Kentucky Nature Preserves Commission (1982). Although phytoplankton communities at Glencoe were dominated by eutrophic species, macroinverlebrate communities reflected good water-quality and habitat conditions. Analysis of fish tissues revealed detectible concentrations of chlordane, PCB's, DDT, methoxychlor, and heavy metals. Bioassays revealed toxicity to fathead minnows during 1986-87. The major point source in the basin was the Owenton waste-water treatment plant, which discharged into Stevens Creek. Bioassays revealed no toxicity to fathead minnows in the effluent or in the receiving stream during July 1986.

Eagle Creek data are given in Table 27.

SUMMARY OF WATER QUALITY

Data collected up to 1990 suggest that water pollution problems existed throughout the Kentucky River Basin. Fecal coliform bacteria in streams was a widespread problem because of inadequate treatment of municipal wastes, failing septic systems, and agriculture. Iron, lead, manganese, mercury, and silver exceeded State standards and Federal guidelines for drinking water and aquatic life at most of the sample sites for a majority of samples. In the Knobs region, chloride discharges from oil and gas operations severely reduced aquatic life in many smaller streams. Organic enrichment and high nutrient loads from waste-water treatment plants and agriculture reduced aquatic life in the Blue Grass region. Several locations were affected by unknown toxins, and detectible levels of heavy metals and the organic pesticides chlordane, aldrin, dieldrin, and DDT were found in fish tissues from the Kentucky River.

Table 25.—Streams Not Fully Supporting Aquatic Life and Recreation in the South Elkhorn Creek Watershed in 1990. From Kentucky Division of Water (1990).

Aquatic Life (miles)	*Cause*	*Source*	*Recreation (miles)*	*Cause*	*Source*
South Elkhorn 41.0	organic enrichment/metals	municipal	17.6	pathogens	municipal/urban runoff
Town Branch 11.3	organic enrichment/metals	municipal	11.3	pathogens	municipal

Table 26.—Water–Quality Parameters Exceeding Standards or Guidelines (Percent of Samples) in the South Elkhorn Creek Watershed. From Smoot and others (1990).

	Federal Guidelines		*Kentucky Standards*		
	Drinking Water	*Aquatic Life*	*Drinking Water*	*Aquatic Life*	*Recreation*
South Elkhorn near Midway					
Low pH	4	4		2	2
Fluoride			32		
Total:					
Nitrogen				23	
Diss. Oxygen		59		47	
Cadmium		19			
Iron	70	2		2	
Lead		58			
Manganese	100		100		
Mercury	5	100		26	
Silver		100			
Zinc		34		34	
Fecal Coliform			8		73

Table 27.—Water–Quality Parameters Exceeding Standards or Guidelines (Percent of Samples) in the Eagle Creek Watershed. From Smoot and others (1990).

	Federal Guidelines		*Kentucky Standards*		
	Drinking Water	*Aquatic Life*	*Drinking Water*	*Aquatic Life*	*Recreation*
Eagle Creek at Glencoe					
Dissolved Solids	1				
Total:					
Nitrogen				1	
Cadmium	1	35		5	
Copper		10			
Iron	73	34		34	
Lead	23	66	23		
Manganese	57		57		
Mercury	15	100		57	
Silver		100			
Zinc		12		12	
Fecal Coliform			2		29

The data discussed above may not fully represent current conditions. Brine discharges from oil and gas operations have reportedly been reduced. Chronic problems at some waste-water treatment plants, such as the Lexington facility on Town Branch, are reportedly in the process of correction. It is clear, however, that despite the best efforts of such agencies as the Division of Water and the Kentucky Nature Preserves Commission, water-quality problems in the basin continue to be widespread and persistent.

REGULATORY ACTIVITIES

The Kentucky Division of Water is charged with protecting the quality of lakes, streams, rivers, and ground water for the entire State, and therefore most, if not all, of its activities apply to the Kentucky River Basin. In its Kentucky Environmental Management Plan, 1990-1992 (KDOW, 1989), the Division of Water outlined its responsibilities and the major issues that needed to be addressed. For each issue, a plan of action was given. This information is summarized below.

Responsibilities

The Division of Water operates water-quality and biological monitoring stations on streams and lakes aroundthe State. Datafromthis monitoring are usedto identify priority areas, to revise State water-quality standards, to aid in developing waste-load allocations, and to determine water-quality trends in Kentucky's surface waters.

The Division is responsible, through its Kentucky Pollutant Discharge Elimination System (KPDES), for controlling the amount of pollutants that cities, industries, and other facilities can discharge into the surface waters of the Commonwealth. Anyone who discharges to a water body must have a KPDES permit. Also, through its 401 Water Ouality Certification Program, the Division is to ensure that discharges to navigable waters comply with provisions of the Federal Clean Water Act.

The Division is responsible for nonpoint-source pollution control and the implementation of Kentucky's Nonpoint Source Pollution Control Program. Nonpointsource pollution, largely unregulated, has been identified as affecting 129 surface-water bodies, seven wetlands, and six ground-water sites in the Kentucky River Basin.

The Division is charged with ensuring that public water systems provide a safe supply of drinking water to Kentucky citizens. To achieve this goal, the Division inspects and monitors public water supplies, reviews and approves plans for treatment plants and distribution systems, trains and provides technical assistance to water plant operators, and educates and informs the public on water-supply problems.

The Division is responsible for the development, promulgation, and amendment of administrative regulations related to water quality and water resources management.

The Division's Wild Rivers Program ensures that the State's most pristine streams are preserved in their natural state.

Issues

Major water-quality issues identified by the Division of Water in the Management Plan were, in no particular order:

1. Increase staff to issue permits in a timely manner or to inspect facilities a sufficient number of times to ensure compliance with permit conditions.
2. Improve the control of toxins and chlorides.
3. Respond to the proliferation of package treatment plants and combined sewer/storm-water systems.
4. Assure compliance with new, more stringent drinking-water requirements.
5. Improve the ambient monitoring network and wild rivers programs.
6. Respond to Federal assistance reductions in waste water, construction grant, and nonpointsource programs.

Division of Water Action Plans, 1990-1992

Compliance and Enforcement

Compliance Sampling Inspections (CSI) consist of a thorough inspection, which includes laboratory analysis of discharge. Routine Inspections consist of a walkthrough inspection of the physical plant. Compliance Evaluation Inspections (CEI) consist of a review of the permittee's self-monitoring and reporting program and an operation and maintenance evaluation. Performance Audit Inspections (PAI) consist of an in-depth verification of a facility's self-monitoring program.

A major part of the action plan was to increase inspection and surveillance staff to work toward the following inspection goals:

Major municipals and industries **(waste-water treatment facilities or industries treating at least 1 million gallons a day):**

Compliance Sampling Inspections: One per year
Routine Inspections: Two per year
Compliance Evaluation Inspections: One per year
Performance Audit Inspections: One every 5 years

Minor municipals **(waste-water treatment facilities treating less than 1 million gallons a day):**

Compliance Sampling Inspections: Every 3 years
Routine Inspections: Two per year
Compliance Evaluation Inspections: One per year
Performance Audit Inspections: Every 5 years

Minor industfies **(treating less than 1 million gallons a day):**

Compliance Sampling Inspections: None
Routine Inspections: One routine inspection, or
Compliance Evaluation Inspections: One per year
Performance Audit Inspections: None

Permitted oil and gas facilities: **One Routine Inspection and one Compliance Evaluation Inspection per year**

Registered oil and gas leases: **One Routine Inspection per year**

Drinking-water systems: **One Comprehensive Inspection and laboratory analysis per year**

Pre-treatment systems:

Comprehensive audit of the municipal waste-water treatment facility pre-treatment program once every 5 years
One pre-treatment compliance inspection per year
One industrial user inspection every 5 years (20 percent of the industries on the municipal system per year)

Section 401 water-quality certification: **Annual inspection**

Wild Rivers:

Aerial survey: Four times a year
Ground survey: Each wild river four times a year
Permit inspection: Every 2 months

The action plan also included increasing staff to seek out unpermitted activities and to ensure timely enforcement of water cases.

Toxin Control Strategies

Under Section 313 of the Federal Superfund Amendments and Reauthorization Act (SARA) of 1986, 328 chemicals were listed as toxic, and 126 priority pollutants were listed in Section 304(1) of the Clean Water Act.

PLAN OF ACTION

1 . Expand the review of municipal permit applications for potential toxic components of their discharge, developing specific limits where needed, and conducting biomonitoring of the whole eff luent for toxicity.

2. Expand the number of pre-treatment verifications.

3. Provide assistance to the Compliance Audit Team regarding toxic impact discharges and the total ambient environment.

Controlling Chlorides

Oil and gas production was the principal industry affected by chloride regulations--oil and gas wells discharge brines in their produced water. As of February 1989, the Division of Water had issued 117 permits, with another 117 in process. Approximately 8,000 oil and gas leases remained for which permits had not been sought.

PLAN OF ACTION

Review, develop, and issue permits with chloride limits.

Provide additional verification and review of pretreatment facilities.

Ensure that dischargers have an opportunity t apply for Underground Injection Control (UI(permits, which would eliminate discharges by r injection.

Increase inspection staff.

Storm Water and Combined Sewer Permits

New Federal Environmental Protection Agency storm-water regulations to minimize impacts of urban runoff would require thousands of additional facilities to apply for surf ace-water discharge permits.

PLAN OF ACTION

Develop a program, based on the provisions of the Clean Water Act, that will meet all legislative requirements for controlling storm-water runoff, including:

1. Regulations for industrial and large municipal sources (population greater than 250,000);

2. Reviewing and processing industrial and large municipal source permit applications;

3. Initiating development of regulations for smaller cities with populations between 100,000 and 250,000;

4. Developing a procedure for issuing general per mits for smaller cities and certain classes of in dustries;

5. Drafting and issuing individual permits for remain ing cities and industries.

Waste-Water Treatment Facilities

The desirability of connecting small waste-water treatment facilities to larger systems has long been recognized. In response to the proliferation of package treatment plants, the Division of Water planned to in crease its consolidation efforts.

Amendments to the Clean Water Act in 1984 gave special attention to bringing municipal sewage plants into compliance by July 1, 1988. The Municipal Coordination Section was formed to provide assistance to municipal treatment plants that were in significant noncompliance.

The Division's waste-water certification, training, and evaluation effort also needed to be expanded to accommodate the approximately 2,800 operators throughout Kentucky.

PLAN OF ACTION

1. Develop alternatives for selective consolidation of small waste-water plants by evaluating current statutes and regulations, establishing guidelines, and offering technical assistance to encourage consolidation.

2. Develop selected permits that will define cutoff dates and force consolidation by denying reissuance when present permits expire.

Increase the number of waste-water training workshops and evaluations.

4. Add personnel and resources for all activities.

Drinking-Water Management

Amendments to the Safe Drinking Water Act (SDWA) provided extensive measures to ensure the protection of drinking water. Implementing those measures required the Division to devote more personnel and resources to those activities.

PLAN OF ACTION

1. Recommend modifications to Kentucky statutes and Natural Resources and Environmental Protection Cabinet regulations to comply with Safe Drinking Water Act amendments.

2. Increase staff, expand the Comprehensive Technical Assistance Program, increase number of training workshops for drinking-water operators, and expand monitoring, compliance, and enforcement system.

3. Develop programs to reduce lead and bacteriological and chemical contaminants in drinking water. Enhance the supplemental fluoridation programs through increased central tracking, review, and follow-up of sampling results, and provide additional technical assistance to ensure that the public is not receiving fluoride at concentrations that could adversely aff ect their health.

4. Evaluate water-treatment techniques and construction plans to ensure effectiveness in complying with regulations, particularly new maximum contaminant levels for volatile organic chemicals, synthetic organic chemicals, inorganic chemicals, and radionuclides.

5. Promote regional public water supplies, and assist with making public water supplies private when it is found to be advantageous.

6. Assist public water supplies in issuing proper notification to consumers when a situation exists that can adversely affect public health. New regulations require a more timely notice to customers, and in many cases, such as for cancer-causing contaminants, require specific wording. A 700 percent increase in the number of public notifications is anticipated.

Ambient Monitoring

Federal funds for monitoring activities were expected to decrease by 54 percent at a time when more monitoring stations were needed, particularly for reference streams (streams as undisturbed as possible).

In recent years, EPA has placed more emphasis on implementation of Section 401 of the Clean Water Act. The Division of Water, likewise, planned to expand its 401 programs.

The Kentucky Wild Rivers System consists of nine streams with a total of 114 stream miles. There are no restrictions on existing land use, but a permit must be obtained for any new land uses in a wild river corridor. Permits have been issued for selective timber harvesting and oil and gas development. Additional resources are required to adequately administer the wild rivers program.

PLAN OF ACTION

1. Use State funds to maintain a portion of the ambient monitoring system that was formerly Federally funded.
2. Establish three to 12 reference stream sites in each of the six physiographic regions of Kentucky (45 total). Determine conditions for chemical water quality, sediment quality, fish tissue residue, habitat condition, and biotic conditions at each reference site.
3. Improve quality of Section 401 reviews. Increase on-site visits and pre-application meetings. Add staff to initiate compliance monitoring and enforcement process. Propose State laws and regulations for Section 401 to maximize the Division's control over certification, compliance monitoring, and enforcement.
4. Add a field position to the Wild Rivers Program to perform compliance monitoring, permit inspections, on-site public relations, post signs, collect river-use data, and sample water quality. Increase frequency of monitoring surveys, complete inventory and management plans for Bad Branch and Martins Fork, and prepare corridor maps for Cumberland, Rockcastle, Rock Creek, and Bad Branch wild rivers. Negotiate and monitor easement agreements for private lands within corridors.

Nonpoint Sources of Water Pollution

Kentucky's nonpoint-source pollution control program is described in two documents. The "Kentucky Nonpoint Source Pollution Assessment Report" (Kentucky Division of Water, 1989b) identifies waters in Kentucky that cannot reasonably be expected to attain or maintain water-quality standards because of nonpoint sources of pollution. The "Kentucky Nonpoint Source Management Program Report"(KDOW, 1989a) identifies Best Management Practices (BMP's) to be used to control nonpoint sources of pollution, and the programs to be used to implement those BMP's.

PLAN OF ACTION

1. Implement the nonpoint-source management program, including educational efforts, technical assistance, research, and BMP demonstration projects.
2. Develop a nonpoint-source sampling strategy and guidelines for monitoring and evaluation.
3. Develop a strategy to control urban nonpoint source pollution, including an education program, identifying implementation agencies, and technical assistance to communities.
4. Explore regulatory options to control nonpoin source pollution Statewide or by critical areas such as Outstanding Resource Waters or domestic water-supply watersheds.

Regulatory Development

The Division of Water bases its actions and activities on administrative regulations. The Division administers separate regulations for waste-water discharges, drinking-water systems, dam safety and flood-plain management, water withdrawal, certification of wastewater treatment plant operators, certification of drinking-water treatment plant operators, and construction review of waste-water treatment plants.

PLAN OF ACTION

1. Provide an additional person to serve as coordinator of regulatory development.
2. Define a formal procedure for the periodic review of existing administrative regulations to ensure that they meet program needs.

Summary of Regulatory Activities

The water-quality responsibilities of the Division of Water are extensive. The primary issue in the 1990-92 Plan was the shortage of personnel and resources to keep up with the rapidly increasing number of regulations. Permitting, monitoring, and enforcement requirements for thousands of pollutant producers and hundreds of pollutants are indeed staggering. Funding and personnel needs seem to grow exponentially. In the 1990-92 Environmental Management Plan, the projected baseline budget (just to do what was done in 1989) for fiscal year 1992 for the Division was $10,485,300, with a staff of 202. To meet the demands of new regulations and programs, the projected fiscal year 1992 budget was $14,858,300, with a staff of 324. The actual fiscal year 1992 budget was $15,489,800, with 286 staff positions.

CONCLUSIONS

The impact of man's activities on water quality in the Kentucky River Basin appears to be widespread and growing. An increasing number of actual and potential pollutants are being identified and regulated. The Kentucky

Department for Environmental Protection (KDEP) recognized that the current regulatory approach could not be indefinitely sustained (KDEP, 1989, p. A-3):

> Environmental protection to date has focused on treating air and water emissions at the and-of-the-pipe or safely disposing of waste after R was produced. We are discovering that the superior approach *is* to eliminate or reduce waste *before* it is generated.

KDEP also recognized that transforming waste streams is often counterproductive. Reducing pollutants in water discharges may increase the land disposal problem. Burning wastes reduces the quantity for land disposal, but may increase toxic concentrations of solids to be disposed of, or produce unacceptable air pollutants. Waste cannot be made to disappear; it must be dispersed into the environment. If concentrations of wastes exceed the local assimilative capacity of the environment, short- or long-term degradation will result, and permanent capacity reduction may occur.

Not only must innovative waste-treatment and prevention technologies be explored, but new institutional approaches to environmental protection must be developed. Economists and environmentalists are currently exploring a variety of pollution control and prevention policies based on economic incentives (taxes, tradeable discharge rights, polluter pays). These approaches need to be examined for application in Kentucky.

Effective water-quality management must consider the quantity and location of all our waste streams-solid, liquid, and gas (air pollutants)-and the ability of the local environment to absorb those wastes. The local and regional assimilative capacity of the environment, given current or anticipated waste-treatment technology, must also be considered when deciding issues of industrial or commercial development, population growth, and land use.

A comprehensive water-quality management framework of necessity must incorporate an entire river basin. A first step in the Kentucky River Basin would be to establish general water-quality policies based on a consensus of interested parties within the basin. These policies could provide the basis for the development of water-quality management plans that would reflect both local and basin wide issues and concerns. Water resource management decisions will not be easy or always popular, but will be necessary to create an environment that will enhance the quality of life in the basin.

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GLOSSARY

Acute toxicity--Short-termwater-quality effects that often result in the death of aquatic organisms.

Aldrin-An organic pesticide.

Alga-Aquaticone-celled or multicellular plants without true stems, roots, and leaves, but containing chlorophyll.

Aquatic-Living or growing in or on the water.

Aquatic habitat-The environment in or on the water in which an aquatic organism lives or grows.

Aquatic life-The plants oranimals living in oron thewater.

Artificial substrate-Device for sampling bottom-dwelling aquatic organisms.

Benthic diatom--Boftorr~-dwelling diatom.

Benthic invertebrate-Minute animal living on the bottom of lakes or streams or attached to stones or other submersed objects.

Benthic macroinvertebrate-Animal larger than 0.6 millimeters living on the bottom of lakes or streams or attached to stones or other submersed objects.

Benthos-Plants and animals living on the bottom of a stream or lake.

Bioaccumulation-The buildup of toxic substances in aquatic organisms.

Bioassay-Any test in which aquatic organisms are used to detect or measure the presence or eff ect of one or more substances, wastes, or environmental factors, alone or in combination, on aquatic organisms.

Chlordane-An organic pesticide.

Chronic toxicity-Long-term water-quality effects that are harmful to individual aquatic organisms and to communities of organisms.

DDT-An organic pesticide.

Diatom-Minute unicellular algae of the class Bacillariophyceae.

Dieldrin-An organic pesticide.

Epipelic-Associated with sediment. Epipelic algae dominate in sediment-laden stream beds.

Epilithic-Attached to rock. Epilithic algae typify undisturbed streams.

Epiphytic-Attached to another plant. Epiphytic diatoms exist in undisturbed streams.

Eutrophic-Having excessive nutrients, resulting in heavy growth of algae and other aquatic plants and restricting the growth of other aquatic life.

Eutrophy-A condition of being nutrient rich.

Fecal coliform bacteria-A group of organisms common to the intestinal tracts of man and animals. The presence of fecal coliform bacteria in water is an indicator of pollution and of potentially dangerous bacterial contamination.

Flocculent-Having a fluffy or woolly appearance.

Halophilic-Requiring or flourishing in saline (salty) water.

Heterotrophic-Deriving nourishment from organic substances.

Invertebrate-Animal without a spine.

Iron ochre--Oxide of iron mixed with sand or clay.

Low-f low augmentation-Release of water to increase downstream f low and water quality during periods of low f low.

Macroinvertebrate-Aquatic invertebrate larger than 0.6 millimeters.

Mesotrophic-In balance with natural nutrient conditions.

Methoxychlor-An organic pesticide.

Nonpoint source-A diffuse source of pollutants not identifiable with a single point orpoints; forexample, uncontrolled runoff from disturbed land, agricultural, or urban areas.

Organic enrichment-An excess of organic matter, which reduces the amount of oxygen in the water and causes stress on aquatic life.

Pathogen-An agent that causes disease, especially a microorganism such as a bacterium or fungus.

PCB-Polychlorinated biphenyl: any of a family of industrial compounds produced by chlorination of biphenyl. An environmental pollutant that accumulates in animal tissue with resultant pathogenic and teratogenic eff ects.

Phytoplankton-Small, floating aquatic plants.

Point source-A source of potential water pollutants that can be identified with a discharge at a single point or points. All significant point-source discharges in Kentucky are subject to permitting and monitoring requirements.

Sediment-Finely divided solid material suspended in water or deposited on the bottom. Usually soil particles eroded from a watershed. Soil erosion occurs naturally, but is accelerated by man's activities (agriculture, mining, construction).

Siftation-Sedimentation, the deposition of suspended soil particles on the bottom of a stream or lake.

Specific conductance-A measure of the ability of water to conduct an electrical current; depends on the quantity and types of ionized substances in the water. Freshly distilled water has a conductivity of about 1 microsiemen per centimeter (gS/cm). The conductivity of drinkable waters in the United States ranges from 50 to 1,500 ILS/ cm. Multiplied by 0.6, the specific conductance in gS/cm can be used to estimate dissolved-solids concentrations in milligrams per liter (mg/L).

Stream channelization-The alteration of a natural stream course by man to suit his various purposes.

Suspended sediment-Sediment that settles from suspension in water relatively slowly.

Teratogenic-Causing fetal malformations.

Toxicity-The quality or degree of being poisonous or harn-dul to plant or animal life.

Turbidity-Darkness or cloudiness of water caused by suspended organic or inorganic matter.

Water-quality parameter-Any characteristic of a water that is usedto describethe quality of thewater relative to certain standards; for example, the concentration of mercury in the water, the amount of sediment in the water, or the temperature, turbidity, or conductivity of the water.

APPENDIX A:

Streams, Lakes, Wetlands, and Ground Waters Affected by Nonpoint–Source Pollution. Modified from Kentucky Division of Water (1990).

		NPS Categories							
Water Body Code	*Stream Name*	*1*	*2*	*3*	*4*	*5*	*Parameters of Concern*	*Monitored/ Evaluated*	*Uses Not Fully Supported*
KY05100201–002	N. Fork, Kentucky River	40	80	51	55	21	BACT, SED, SO_4, MET	monitored	PCR
KY05100201–003	Devil Creek	50	51	55	20		SED, MET, SO4, CL, pH, Fe	evaluated	
KY05100201–003	Walkers Creek	55	21	23			SED, CL	evaluated	
KY05100201–004	Frozen Creek	80	11				SED	evaluated	
KY05100201–004	Boone Fk., Frozen Cr.	80	11				SED	evaluated	
KY05100201–005	N. Fork, Kentucky River	40	10	50	80	51	BACT, SED, SO4, MET	monitored	PCR, WAH
KY05100201–006	Caney Creek	80					SED	evaluated	
KY05100201–007	S. Fork, Quicksand Cr.	10	51	80			BACT, SED	monitored	PCR
KY05100201–007	Spring Fork	50					SED	evaluated	WAH
KY05100201–007	Quicksand Creek	10	51	55	65	80	BACT, NUTR, SO_4, SED, CL	monitored	PCR
KY05100201–008	N. Fork, Kentucky River	80	51	55	20		SED, SO4, MET	evaluated	
KY05100201–009	Troublesome Creek	60	40	51	52	55	BACT, SO4, MET, SED	monitored	PCR
KY05100201–009	Buckhorn Creek	51	65				SED, NUTR, BACT	evaluated	
KY05100201–009	Lost Creek	50	80				SED, NUTR, BACT	evaluated	WAH
KY05100201–009	Balls Fork	65	80	51	32		SED, NUTR, BACT	evaluated	
KY05100201–010	N. Fork, Kentucky River	51	52	80	55	21	SED, SO4, MET	evaluated	
KY05100201–011	Big Creek	51	52	55	32	23	SED, SO4, MET	evaluated	
KY05100201–011	Grapevine Creek	51	52	80	32		SED, SO4, MET	evaluated	
KY05100201–012	N. Fork, Kentucky River	51	52	80	55	32	SED, MET, AS, CL, SO4	evaluated	
KY05100201–013	Lotts Creek	51	52	65	80	32	SED, SO4, MET	evaluated	
KY05100201–016	Carr Fork Creek	51	52	80	57		SED, SO4, MET	evaluated	
KY05100201–017	N. Fork, Kentucky River	51	80	11	52	32	SED, AS, MET, CL	evaluated	
KY05100201–018	Leatherwood Creek	51	52	80	57	55	SO4, SED, MET, CL	evaluated	
KY05100201–019	Turkey Creek	51	80	21	55		SO4, SED, MET, CL	evaluated	

		NPS Categories							
Water Body Code	*Stream Name*	*1*	*2*	*3*	*4*	*5*	*Parameters of Concern*	*Monitored/ Evaluated*	*Uses Not Fully Supported*
KY05100201–020	Maces Creek	51	52	55	23	80	SO4, SED, MET, CL	evaluated	
KY05100201–021	Rockhouse Creek	50	51	57	80	21	SED, MET, SO4	evaluated	WAH
KY05100201–022	Millstone Creek	51	80	63	21		SED, MET, SO4	evaluated	
KY05100202–001	Middle Fk., Ky. River	10	51	11	52	80	BACT, SED, MET, SO4, CL	monitored	PCR, WAH–threatened
KY05100202–002	Turkey Creek	11					SED, CL, MET	evaluated	
KY05100202–002	Long Creek	51	52	80	23	21	SED	evaluated	
KY05100202–006	Cutshin Creek	50	51	80	55	52	Oil–Grease, SED, MET, SO4, CL	evaluated	WAH
KY05100202–006	Raccoon Creek	50					Oil–Grease, SED	evaluated	WAH
KY05100202–007	Middle Fk., Ky. River	51	57	52	21	80	SED, MET, SO4, CL, BACT	evaluated	
KY05100202–008	Rockhouse Creek	32	80	21	55	51	SED, MET, SO4, CL	evaluated	
KY05100202–009	Greasy Creek	51	52	80	14	32	SED, MET, SO4, CL	evaluated	
KY05100202–010	Middle Fk., Ky. River	51	57	52	21	80	SED, MET, SO4, CL, BACT	evaluated	
KY05100202–010	Beech Fork	51	52	80	55	32	SED, MET, SO4, CL	evaluated	
KY05100203–001	South Fk., Ky. River	50	20	51	80	11	SED, BACT, CL	monitored	WAH–threatened
KY05100203–002	Sexton Creek	57	51	85	11	20	SED, MET, SO4, CL, NUTR, BACT	evaluated	
KY05100203–003	Upper Buffalo Creek	51					SED, MET, SO4	evaluated	
KY05100203–004	Bullskin Creek	20	51	52	80	55	SED, MET, SO4, CL, NUTR	evaluated	
KY05100203–005	Cow Creek	51	11				SED, MET, SO4	evaluated	
KY05100203–005	Indian Creek	51	11				SED, MET, SO4	evaluated	
KY05100203–005	Island Creek	51	11				SED, MET, SO4	evaluated	
KY05100203–005	Buck Creek	80	51	11			SED	evaluated	
KY05100203–005	Jones Fork	80	65	51	32		SED, NUTR, BACT	evaluated	
KY05100203–005	Right Fk., Beaver Creek	51	65	80	32		SED, NUTR, BACT	evaluated	
KY05100203–005	Meadow Creek	80	32				SED	evaluated	
KY05100203–006	Goose Creek	51	20	14	11	77	SED, MET, SO4, CL, NUTR, BACT	evaluated	
KY05100203–010	Goose Creek	51	20	14	11	77	SED, MET, SO4, CL, NUTR, BACT	evaluated	
KY05100203–011	Redbird River	20	51	14	11	62	SO4, SED, MET, NUTR, BACT	evaluated	
KY05100204–001	Kentucky River	11	22	55	80	51	CL, SED, NUTR, BACT	evaluated	

		NPS Categories							
Water Body Code	*Stream Name*	*1*	*2*	*3*	*4*	*5*	*Parameters of Concern*	*Monitored/ Evaluated*	*Uses Not Fully Supported*
KY05100204–001	Campbell Creek	22	55	80			SED, CL	evaluated	
KY05100204–002	Drowning Creek	11	65	32	14	22	SED, NUTR	evaluated	
KY05100204–004	Red Lick Creek	11	65	22	55	80	CL, SED, NUTR, BACT	evaluated	
KY05100204–006	S. Fk., Station Camp Cr.	55	18	85	80	22	CL, SED, MET, NUTR, SO4	evaluated	
KY05100204–008	Kentucky River	11	22	55	80	51	SED, MET, NUTR, CL, SO4, BACT	evaluated	
KY05100204–008	Cow Creek	55	80				CL, SED	evaluated	
KY05100204–009	Big Sinking Creek	50					CL, TDS	monitored	WAH
KY05100204–009	Billey Fork	50					CL, TDS	monitored	WAH
KY05100204–009	Millers Creek	50	55	22	11	80	CL, TDS, SED, MET, NUTR, SO4	monitored	WAH
KY05100204–010	Kentucky River	10	51	11	80	22	BACT, SED, MET, NUTR, SO4, CL	monitored	PCR, WAH–threatened
KY05100204–011	Sturgeon Creek	57	85	80	51		SED, MET, NUTR, SO4	evaluated	
KY05100204–013	Red River	55	22	65	11	20	CL, NUTR, SO4, BACT	monitored	
KY05100204–014	Lulbegrud Creek	11	14	21	23	31	SED, BACT	evaluated	
KY05100204–015	Hardwick Creek	10	20				SED	evaluated	
KY05100204–016	Cane Creek	11	21	80			SED	evaluated	
KY05100204–018	South Fork, Red River	55					CL, TDS	evaluated	WAH
KY05100204–018	Sand Lick Fork	55					CL, TDS	evaluated	WAH
KY05100204–019	Red River	70	50	21	80		SED, MET	monitored	WAH
KY05100204–023	Stillwater Creek	10	60	65	20		SED, BACT	evaluated	
KY05100204–025	Red River	70	50	10	60	65	SED, MET, Fe, Mn	monitored	WAH
KY05100204–025	Lacy Creek	10	20	51			SED	evaluated	
KY05100204–025	Gillmore Creek	10	20	51	40		SED, NUTR	evaluated	
KY05100205–001	Kentucky River	11	18	32	40		SED, NUTR, MET	evaluated	
KY05100205–002	Whites Run Creek	11	18	32	40		SED, NUTR, MET	evaluated	
KY05100205–002	Mill Creek	11	18	14	32	40	SED, NUTR, MET	evaluated	
KY05100205–004	Ten Mile Creek	80	10	65			SED, NUTR, BACT	evaluated	
KY05100205–006	Clarks Creek	80	10	65			SED, NUTR, BACT	evaluated	
KY05100205–008	Grassy Run	80	10	65			SED, NUTR, BACT	evaluated	

		NPS Categories							
Water Body Code	*Stream Name*	*1*	*2*	*3*	*4*	*5*	*Parameters of Concern*	*Monitored/ Evaluated*	*Uses Not Fully Supported*
KY05100205–008	Brush Creek	80	65	10			SED, NUTR, BACT	evaluated	
KY05100205–010	Eagle Creek	11	12	14	22	20	As, SED, Oil–Grease, BACT, MET	evaluated	
KY05100205–012	Big Twin Creek	80	65	10			SED, NUTR, BACT	evaluated	
KY05100205–013	Sulphur Creek	11	14				SED	evaluated	
KY05100205–013	Drennon Creek	11	14				SED	evaluated	
KY05100205–013	Caines Run	11	14				SED	evaluated	
KY05100205–014	Six Mile Creek	11	14				SED	evaluated	
KY05100205–015	Severn Creek	80	65	10			SED, NUTR, BACT	evaluated	
KY05100205–016	Sawridge Creek	80	65	10			SED, NUTR, BACT	evaluated	
KY05100205–016	Cedar Creek	80	65	10			SED, NUTR, BACT	evaluated	
KY05100205–017	Flat Creek	11	14				SED	evaluated	
KY05100205–017	Mill Creek	80	65	10			SED, NUTR, BACT	evaluated	
KY05100205–021	Cane Run Creek	90	11	12	14	32	MET, SED, NUTR, BACT	monitored	WAH
KY05100205–026	South Elkhorn Creek	40	11	80	32	40	ORG, DO, BACT, MET, LIND, SED	monitored	WAH, PCR
KY05100205–029	South Elkhorn Creek	11	80	32	40		LIND, SED, MET, CL, DDT	evaluated	
KY05100205–031	Stoney Creek	11	14				SED	evaluated	
KY05100205–032	N. & S. Benson Creeks	11	12	14	65		SED, NUTR, BACT	evaluated	
KY05100205–033	Kentucky River	90	11	14	32	65	BACT, SED, NUTR	monitored	PCR
KY05100205–034	Glenns Creek	11	40	80	14		SED, MET	evaluated	
KY05100205–035	Clear Creek	11	80	14	20		SED	evaluated	
KY05100205–036	Shaker Creek	11	14				SED	evaluated	
KY05100205–036	Craig Creek	11	80	14	20		SED	evaluated	
KY05100205–037	Dix River	11	16	65	32		SED, BACT	evaluated	
KY05100205–039	Clarks Run	62	65	32	14		SED, BACT, NUTR	evaluated	
KY05100205–040	Spears Creek	14	32				SED, BACT, NUTR	evaluated	
KY05100205–041	Dix River	11	16	65	32		SED, BACT	evaluated	
KY05100205–042	Harris Creek	11	12	14	13		SED	evaluated	
KY05100205–042	Hanging Fork	11	80	18	65		SED, BACT, NUTR	evaluated	

		NPS Categories							
Water Body Code	*Stream Name*	*1*	*2*	*3*	*4*	*5*	*Parameters of Concern*	*Monitored/ Evaluated*	*Uses Not Fully Supported*
KY05100205–043	Dix River	11	80	18	65	61	SED, NUTR, BACT, SO4, MET	evaluated	
KY05100205–044	Logan Creek	11	18	80	32		SED, NUTR. BACT	evaluated	
KY05100205–047	Kentucky River	90	11	40	14	32	BACT, SED, NUTR	monitored	PCR
KY05100205–048	Jessamine Creek	40	30	65			SED, NUTR, BACT, MET	evaluated	
KY05100205–049	Hickman Creek	32	40	64			SED, NUTR, BACT, MET	evaluated	
KY05100205–050	Sugar Creek	11	18	22			SED, NUTR, BACT	evaluated	
KY05100205–051	Paint Lick Creek	11	16	18	32		SED, BACT	evaluated	
KY05100205–052	Silver Creek	32	65	11	40		PEST, SED, NUTR	evaluated	
KY05100205–053	Tate Creek	32	65	40	11		SED	evaluated	
KY05100205–054	Boone Creek	80	14	11	32		SED	evaluated	
KY05100205–055	Otter Creek	32	65	40	11		PEST, SED, NUTR	evaluated	
KY05100205–056	Four Mile Creek	70					SED	evaluated	
KY05100205–057	Upper Howard Creek	70	10				SED	evaluated	
KY05100205–058	Muddy Creek	32	65	66	63		SED, BACT	evaluated	
KY05100205–059	Elk Lick	50	70				TDS	monitored	WAH
KY05100205–059	Lower Howard Creek	80					SED	evaluated	
KY05100205–059	Canoe Creek	11	18	22			SED, NUTR, BACT	evaluated	

Water Body Code	Lake Name	NPS Categories 1	2	3	4	5	Parameters of Concern	Monitored/ Evaluated	Uses Not Fully Supported
LAKES									
KY05100201-015	Carr Fork Lake	51	80	65	32		SED, BACT	monitored	SCR
KY05100202-003	Buckhorn Lake	51	80	21	52	55	SED	monitored	SCR
KY05100205-038	Herrington Lake	10	65	11	16	32	NUTR, SED, BACT	monitored	WAH
KY05100205-052L01	Wilgreen Lake	65					NUTR	monitored	WAH, SCR

Water Body Code	Watershed	County	NPS Categories 1	2	3	Parameters of Concern	Monitored/ Evaluated	Uses Not Fully Supported
WETLANDS								
KY05100201	Buckhorn Creek	Breathitt	51			MET, SO4, SP COND	evaluated	
KY05100201	Troublesome Creek	Perry	51			SP COND, SO4, MET, Na	evaluated	
KY05100201	Carr Fork	Knott	51	52		SED, MET, SO4, Na, SP COND	evaluated	
KY05100201	Squabble Creek	Perry	51	71	62	SED, SO4, MET, Na, SP COND, BACT, NUTR	evaluated	
KY05100203	Goose Creek	Clay	51			SED	evaluated	
KY05100203	Buck Creek	Owsley	51	10		SED, SO4, MET	evaluated	
KY05100204	Sturgeon Creek	Lee	51	10		SED	evaluated	

		NPS Categories						
Ground–Water Body Name	*County or Region*	*1*	*2*	*3*	*4*	*5*	*Parameters of Concern*	*Monitored/ Evaluated*
Inner Bluegrass karst aquifers	Anderson, Boyle, Bourbon, Clark, Fayette, Franklin, Garrard, Jessamine, Madison, Mercer, Scott, Woodford	10	40				bacteria, nitrates	monitored
North Fork of Kentucky River ground–water basin	Lee, Breathitt, Perry	51					metals, acid	evaluated
Royal Spring aquifer	Scott	11	14	16	18	61	bacteria	evaluated
Unnamed ground–water site near Frankfort	Franklin	90					fuel	evaluated
Unnamed ground–water site near Lexington	Fayette	90					fuel	evaluated
Unnamed ground–water site near Lexington	Fafyette	90					organics	evaluated

Parameter Abbreviations

Agriculture		Iron	Fe
Total Suspended Solids	TSS	Specific Conductance	SP COND
Sediment	SED	Petroleum	
Pesticides	PEST	Chlorides	CL
Lindane	LIND	Total Organic Carbon	TOC
Dichloro–diphenyl–trichloroethane	DDT	Urban	
Nutrients (ammonia, phosphorous)	NUTR	Arsenic	As
Bacteria	BACT	Polychlorinated–biphenyls	PCB
Dissolved Oxygen	DO	Total Dissolved Solids	TDS
Mining		Bromide	Br
Acidity	ACID	Sodium	Na
Manganese	Mn	Calcium	Ca
Sulfates	SO4	Volatile Organic Compounds	VOC
Aluminum	Al	Organics	ORG
Metals	MET	Fuel (gasoline, diesel)	FUEL

Nonpoint–Source Category Codes

10 Agriculture
- 11 Non–irrigated crop production
- 12 Irrigated crop production
- 13 Specialty crop production
- 14 Pasture land
- 15 Range land
- 16 Feedlot—all types
- 17 Aquaculture
- 18 Animal management areas
- 19 Manure lagoons

20 Forestry
- 21 Harvesting, reforestation
- 22 Forest management
- 23 Road construction

30 Construction
- 31 Highway, road, bridge
- 32 Land development

40 Runoff/Storm Sewers

Includes runoff from residential, commercial, industrial, and park–land areas not covered under other source categories

50 Resource Extraction
- 51 Surface mining
- 52 Subsurface mining
- 53 Placer mining
- 54 Dredge mining
- 55 Petroleum activities
- 56 Mill tailings
- 57 Mine tailings

60 Land Disposal
- 61 Sludge
- 62 Waste water
- 63 Landfills
- 64 Industrial land treatment
- 65 On–site waste–water systems (septic tanks, etc.)
- 66 Hazardous waste

70 Hydrologic–Habitat Modification
- 71 Channelization
- 72 Dredging
- 73 Dam construction
- 74 Flow regulation
- 75 Bridge construction
- 76 Vegetation removal
- 77 Streambank modification–destabilization
- 78 Draining–filling of wetlands

80 Other
- 81 Atmospheric deposition
- 82 Waste storage–storage tank leaks
- 83 Highway runoff
- 84 Spills
- 85 In–place contaminants
- 86 Natural
- 87 Recreational activities
- 88 Upstream impoundments
- 89 Salt storage site

90 Unknown

APPENDIX B:

Percentage of Water–Quality Measurements Not Meeting Criteria. Modified from Smoot and Others (1990).

			Percentage Not Meeting Indicated Criteria								
Site Number	*Station Name*	*Number Measured*	*Max. Contaminant Level*	*Max. Con. Level Goal*	*Proposed Max. Con. Level Goal*	*Secondary Max. Con. Level*	*Aquatic Life Acute*	*Aquatic Life Chronic*	*Ky. Domestic Water Supply*	*Ky. Warm–Water Aquatic Habitat*	*Ky. Recreational Water, Secondary*
pH below criteria											
0.1	Yonts Fork near Neon	13				15		15		8	8
2.3	Middle Fork of Kentucky River at Tallega	61				8		8			
2.6	South Fork of Kentucky River at Booneville	58				5		5			
3.0	Kentucky River at Lock 14 at Heidelberg	91				1		1			
3.1	Red River near Hazel Green	102				5		5			
7.0	Kentucky River above Frankfort	83				1		1			
9.0	Kentucky River below Frankfort	73				1		1		1	1
9.3	South Elkhorn Creek near Midway	44				4		4		2	2
10.0	Kentucky River at Lock 2, at Lockport	101				3		3			
pH above criteria											
3.0	Kentucky River at Lock 14 at Heidelberg	91				1					
3.2	Red River near Bowen	68				2		2		2	2
5.0	Kentucky River at Camp Nelson	75				1					
7.0	Kentucky River above Frankfort	83				1					
9.0	Kentucky River below Frankfort	73				3					
10.0	Kentucky River at Lock 2 at Lockport	101				1					
Alkalinity											
2.1	Middle Fork of Kentucky River near Hyden	21						19			

			Percentage Not Meeting Indicated Criteria								
Site Number	*Station Name*	*Number Measured*	*Max. Contaminant Level*	*Max. Con. Level Goal*	*Proposed Max. Con. Level Goal*	*Secondary Max. Con. Level*	*Aquatic Life Acute*	*Aquatic Life Chronic*	*Ky. Domestic Water Supply*	*Ky. Warm–Water Aquatic Habitat*	*Ky. Recreational Water, Secondary*
2.2	Cutshin Creek at Wooton	10						10			
2.3	Middle Fork of Kentucky River at Tallega	60						12			
2.5	Goose Creek at Manchester	19						37			
2.6	South Fork of Kentucky River at Booneville	57						12			
3.1	Red River near Hazel Green	99						28			
7.0	Kentucky River above Frankfort	81						1			
Dissolved solids, residue on evaporation at 180 degrees Celsius											
2.0	North Fork of Kentucky River at Jackson	52				6					
3.0	Kentucky River at Lock 14 at Heidelberg	80				1					
5.0	Kentucky River at Camp Nelson	64				2					
10.1	Eagle Creek at Glencoe	84				1					
Fluoride, dissolved											
9.3	South Elkhorn Creek near Midway	34							32		
Nitrogen, total un–ionized ammonia											
3.0	Kentucky River at Lock 14 at Heidelberg	78								1	
9.0	Kentucky River below Frankfort	71								1	
9.3	South Elkhorn Creek near Midway	22								23	
10.1	Eagle Creek at Glencoe	83								1	
Dissolved oxygen											
9.3	South Elkhorn Creek near Midway	17					18	59		47	
Arsenic, total											
3.0	Kentucky River at Lock 14 at Heidelberg	75	1		1					1	
10.0	Kentucky River at Lock 2 at Lockport	101	1		1					1	

Site Number	Station Name	Number Measured	Percentage Not Meeting Indicated Criteria								
			Max. Contaminant Level	*Max. Con. Level Goal*	*Proposed Max. Con. Level Goal*	*Secondary Max. Con. Level*	*Aquatic Life Acute*	*Aquatic Life Chronic*	*Ky. Domestic Water Supply*	*Ky. Warm–Water Aquatic Habitat*	*Ky. Recreational Water, Secondary*
Cadmium, total recoverable											
2.0	North Fork of Kentucky River at Jackson	36			3		3	6			
2.3	Middle Fork of Kentucky River at Tallega	35						11			
2.6	South Fork of Kentucky River at Booneville	35						11			
3.0	Kentucky River at Lock 14 at Heidelberg	61	2		7		10	19		2	
3.1	Red River near Hazel Green	68	3		4		6	26		3	
5.0	Kentucky River at Camp Nelson	62	10		13		18	25		8	
7.0	Kentucky River above Frankfort	62	11		13		16	28		10	
9.0	Kentucky River below Frankfort	55	14		20		20	33		14	
9.3	South Elkhorn Creek near Midway	43					2	19			
10.1	Eagle Creek at Glencoe	74	1		1		1	35		5	
Chromium, total recoverable											
3.1	Red River near Hazel Green	76	1						1		
Copper, total recoverable											
2.0	North Fork of Kentucky River at Jackson	36					6	8			
2.3	Middle Fork of Kentucky River at Tallega	36					3	6			
2.6	South Fork of Kentucky River at Booneville	35					3	6			
3.0	Kentucky River at Lock 14 at Heidelberg	84					7	16			
3.1	Red River at Hazel Green	90					3	11			
5.0	Kentucky River at Camp Nelson	74					3	8			
7.0	Kentucky River above Frankfort	82					17	21			
9.0	Kentucky River below Frankfort	72					4	8			
10.0	Kentucky River at Lock 2 at Lockport	27					35	46			

Site Number	Station Name	Number Measured	Percentage Not Meeting Indicated Criteria: Max. Contaminant Level	Max. Con. Level Goal	Proposed Max. Con. Level Goal	Secondary Max. Con. Level	Aquatic Life Acute	Aquatic Life Chronic	Ky. Domestic Water Supply	Ky. Warm–Water Aquatic Habitat	Ky. Recreational Water, Secondary
10.1	Eagle Creek at Glencoe	86					7	10			
Iron, total recoverable											
0.1	Yonts Fork near Neon	13				77		54		54	
1.0	North Fork of Kentucky River at Hazard	18				100		72		72	
2.0	North Fork of Kentucky River at Jackson	53				96		58		58	
2.1	Middle Fork of Kentucky River near Hyden	21				100		52		52	
2.3	Middle Fork of Kentucky River at Tallega	51				92		47		47	
2.5	Goose Creek at Manchester	19				100		84		84	
2.6	South Fork of Kentucky River at Booneville	47				87		28		28	
3.0	Kentucky River at Lock 14 at Heidelberg	66				80		30		30	
3.1	Red River near Hazel Green	80				94		35		35	
5.0	Kentucky River at Camp Nelson	64				59		28		28	
7.0	Kentucky River above Frankfort	65				57		25		25	
9.0	Kentucky River below Frankfort	56				59		25		25	
9.3	South Elkhorn Creek near Midway	40				70		2		2	
10.0	Kentucky River at Lock 2 at Lockport	27				96		52		52	
10.1	Eagle Creek at Glencoe	73				73		34		34	
Lead, total recoverable											
2.0	North Fork of Kentucky River at Jackson	36			100			50			
2.3	Middle Fork of Kentucky River at Tallega	35			100			49			
2.6	South Fork of Kentucky River at Booneville	35	3		100		3	60	3		
3.0	Kentucky River at Lock 14 at Heidelberg	69	9		100		4	70	9		

			Percentage Not Meeting Indicated Criteria								
Site Number	*Station Name*	*Number Measured*	*Max. Contaminant Level*	*Max. Con. Level Goal*	*Proposed Max. Con. Level Goal*	*Secondary Max. Con. Level*	*Aquatic Life Acute*	*Aquatic Life Chronic*	*Ky. Domestic Water Supply*	*Ky. Warm–Water Aquatic Habitat*	*Ky. Recreational Water, Secondary*
3.1	Red River near Hazel Green	75	7		100		4	58	7		
5.0	Kentucky River at Camp Nelson	66	12		100		12	81	12		
7.0	Kentucky River above Frankfort	71	13		100		8	68	13		
9.0	Kentucky River below Frankfort	63	22		100		19	73	22		
9.3	South Elkhorn Creek near Midway	43			100			58			
10.0	Kentucky River at Lock 2 at Lockport	25			100			96			
10.1	Eagle Creek at Glencoe	75	23		100		19	66	23		
Manganese, total recoverable											
0.1	Yonts Fork near Neon	13				100			100		
1.0	North Fork of Kentucky River at Hazard	18				94			94		
2.0	North Fork of Kentucky River at Jackson	53				94			94		
2.1	Middle Fork of Kentucky River near Hyden	21				86			86		
2.3	Middle Fork of Kentucky River at Tallega	50				96			96		
2.5	Goose Creek at Manchester	19				100			100		
2.6	South Fork of Kentucky River at Booneville	47				92			92		
3.0	Kentucky River at Lock 14 at Heidelberg	64				94			94		
3.1	Red River near Hazel Green	79				99			99		
5.0	Kentucky River at Camp Nelson	62				76			76		
7.0	Kentucky River above Frankfort	64				56			56		
9.0	Kentucky River below Frankfort	55				64			64		
9.3	South Elkhorn Creek near Midway	41				100			100		
10.0	Kentucky River at Lock 2 at Lockport	27				96			96		
10.1	Eagle Creek at Glencoe	74				57			57		

			Percentage Not Meeting Indicated Criteria								
Site Number	*Station Name*	*Number Measured*	*Max. Contaminant Level*	*Max. Con. Level Goal*	*Proposed Max. Con. Level Goal*	*Secondary Max. Con. Level*	*Aquatic Life Acute*	*Aquatic Life Chronic*	*Ky. Domestic Water Supply*	*Ky. Warm–Water Aquatic Habitat*	*Ky. Recreational Water, Secondary*
Mercury, total recoverable											
2.0	North Fork of Kentucky River at Jackson	37	5		3		5	100		30	
2.3	Middle Fork of Kentucky River at Tallega	35						100		14	
2.6	South Fork of Kentucky River at Booneville	35	3		3		3	100		17	
3.0	Kentucky River at Lock 14 at Heidelberg	68	10		9		9	100		56	
3.1	Red River near Hazel Green	71	4		3		3	100		54	
5.0	Kentucky River at Camp Nelson	58	9		5		7	100		50	
7.0	Kentucky River above Frankfort	70	10		6		9	100		64	
9.0	Kentucky River below Frankfort	56	7		4		7	100		64	
9.3	South Elkhorn Creek near Midway	43	5		5		5	100		26	
10.0	Kentucky River at Lock 2 at Lockport	24						100		60	
10.1	Eagle Creek at Glencoe	60	15		8		13	100		57	
Silver, total recoverable											
2.0	North Fork of Kentucky River at Jackson	21						100			
2.6	South Fork of Kentucky River at Booneville	21						67			
3.0	Kentucky River at Lock 14 at Heidelberg	30						80			
3.1	Red River near Hazel Green	31						100			
5.0	Kentucky River at Camp Nelson	29						100			
7.0	Kentucky River above Frankfort	30						100			
9.0	Kentucky River below Frankfort	30						100			
9.3	South Elkhorn Creek near Midway	28						100			
10.0	Kentucky River at Lock 2 at Lockport	15						9			
10.1	Eagle Creek at Glencoe	31						100			

			Percentage Not Meeting Indicated Criteria								
Site Number	*Station Name*	*Number Measured*	*Max. Contaminant Level*	*Max. Con. Level Goal*	*Proposed Max. Con. Level Goal*	*Secondary Max. Con. Level*	*Aquatic Life Acute*	*Aquatic Life Chronic*	*Ky. Domestic Water Supply*	*Ky. Warm-Water Aquatic Habitat*	*Ky. Recreational Water, Secondary*
Zinc, total recoverable											
2.0	North Fork of Kentucky River at Jackson	34						18		18	
2.3	Middle Fork of Kentucky River at Tallega	33						15		15	
2.6	South Fork of Kentucky River at Booneville	33						12		12	
3.0	Kentucky River at Lock 14 at Heidelberg	61						20		20	
3.1	Red River near Hazel Green	70						3		3	
5.0	Kentucky River at Camp Nelson	64						8		8	
7.0	Kentucky River above Frankfort	65						14		14	
9.0	Kentucky River below Frankfort	56						9		9	
9.3	South Elkhorn Creek near Midway	41						34		34	
10.0	Kentucky River at Lock 2 at Lockport	27						37		37	
10.1	Eagle Creek at Glencoe	65					2	12		12	

			Percentage Not Meeting Indicated Criteria		
Site Number	*Station Name*	*Number Measured*	*Ky. Domestic Water Supply*	*Ky. Recreational Water, Primary*	*Ky. Recreational Water, Secondary*
Coliform, fecal, membrane filtered, M-FC medium at 44.5 degrees Celsius					
2.0	North Fork of Kentucky River at Jackson	26	35	92	58
2.3	Middle Fork of Kentucky River at Tallega	25	4	24	8
2.6	South Fork of Kentucky River at Booneville	25		40	12
3.0	Kentucky River at Lock 14 at Heidelberg	61	3	49	15
3.1	Red River at Hazel Green	59	7	66	15
5.0	Kentucky River at Camp Nelson	62	6	23	6
7.0	Kentucky River above Frankfort	64		22	3
9.0	Kentucky River below Frankfort	61	2	36	8
9.3	South Elkhorn Creek near Midway	26	8	73	15
10.0	Kentucky River at Lock 2 at Lockport	12	17	75	25
10.1	Eagle Creek at Glencoe	68	2	29	10
Coliform, fecal, 0.7 micrometer, membrane filtered					
10.0	Kentucky River at Lock 2 at Lockport	80	11	50	28
Streptococci, fecal, membrane filtered, KF agar					
10.0	Kentucky River at Lock 2 at Lockport	76	16	47	20

APPENDIX C: Selected Kentucky Surface–Water–Quality Criteria

Constituent or Property	*Domestic Water Supply*	*Warm–Water Aquatic Habitat*	*Cold–Water Aquatic Habitat*	*Recreational Waters*
Ammonia, total un–ionized, mg/L		0.05		
Arsenic, total, µg/L as As		50		
Barium, total, µg/L as Ba	1,000			
Beryllium, total, µg/L as Be		11 (soft) 1,100 (hard)		
Cadmium, total, µg/L as Cd		4 (soft) 12 (hard)		
Chloride, dissolved, mg/L as Cl	250	600		
Chromium, total, µg/L as Cr	50	100		
Copper, total, in µg/L as Cu	1,000			
Cyanide, total, µg/L as Cn		5		
Dissolved oxygen, mg/L		<4	<5	
Dissolved solids, total, mg/L	750			
Fecal coliform bacteria, colonies/100 ml	2,000			200*, 1,000**
Fluoride, dissolved, mg/L as F	1			
Iron, total, µg/L as Fe		1,000		
Lead, total, µg/L as Pb	50			
Manganese, total, µg/L as Mn	50			
Mercury, total, µg/L as Hg		0.2		
Nitrogen, total nitrate, mg/L as N	10			
pH, standard units		6.0–9.0		6.0–9.0
Selenium, total, in µg/L as Se	10			
Silver, total, µg/L as Ag	50			
Sulfate, dissolved, mg/L as SO_4	250			
Temperature, degrees Celsius		<31.7	***	
Zinc, total, µg/L as Zn		47		

Notes:

Standards used for evaluation in Smoot and others (1990). Source: Kentucky Natural Resources and Environmental Protection Cabinet (1985).

mg/L = milligrams per liter

µg/L = micrograms per liter

< = less than

mL = milliliters

* = primary contact recreation

** = secondary contact recreation

*** = not to exceed natural seasonal variations

soft = water has an equivalent concentration of calcium carbonate of 0 to 75 milligrams per liter

hard = water has an equivalent concentration of calcium carbonate of over 75 milligrams per liter

Warm–water aquatic habitat criteria apply where none are established for cold–water aquatic habitat.

APPENDIX D: Selected EPA Water–Quality Criteria for Fresh–Water Aquatic Life

Constituent of Property	*Aquatic Life Acute*[1]	*Aquatic Life Chronic*[2]
Alkalinity, mg/L as $CaCO_3$		<20
Ammonia, total, mg/L	Criteria pH and temperature dependent	
Arsenic, total trivalent, µg/L as As	360	190
Cadmium, total, µg/L as Cd	3.9*	1.1*
Chromium, total, µg/L as Cr		
Chromium, hexavalent	16	11
Chromium, trivalent	1,700*	210*
Copper, total, in µg/L as Cu	18*	12*
Cyanide, total, µg/L as Cn	0.22	0.0052
Dissolved oxygen, mg/L	<3–4	<5.5
Iron, total, µg/L as Fe		1,000
Lead, total, µg/L as Pb	82*	3.2*
Mercury, total, µg/L as Hg	2.4	0.012
Nickel, total, µg/L as Ni	1,800*	96*
pH, standard units		6.5–9.0
Phenol, µg/L	10,200**	2,560**
Phthalate esters, µg/L	940**	9**
Selenium, total, in µg/L as Se	260	35
Silver, total, µg/L as Ag	4.1*	0.12
Temperature, degrees Celsius	Species–dependent criteria	
Zinc, total, µg/L as Zn	320*	47

Notes:
Standards used for evaluation in Smoot and others (1990). Source: U.S. Environmental Protection Agency (1986a).
mg/L = milligrams per liter
µg/L = micrograms per liter
< = less than
* = hardness level of 100 mg used to calculate criteria
** = lowest observed effect level
1 Highest 1–hour average concentration that should not cause unacceptable toxicity to aquatic organisms during short–term exposure.
2 Highest 4–day average concentration that should not cause unacceptable toxicity to aquatic organisms during long–term exposure.

APPENDIX E: Selected EPA Drinking–Water Standards. After Smoot and others (1990).

Constituent or Property	*MCL*	*MCLG*	*PMCL*	*PMCLG*	*SMCL*
Arsenic, total, µg/L as As	50			50	
Barium, total, µg/L as Ba	1000			1,500	
Cadmium, total, µg/L as Cd	10			5	
Chloride, dissolved, mg/L as CL					250
Chromium, total, µg/L as Cr	50			120	
Copper, total, in µg/L as Cu			1,300	1,300	1,000
Dissolved solids, total, mg/L					500
Fluoride, dissolved, mg/L as F	4	4			2
Iron, total, µg/L as Fe					300
Lead, total, µg/L as Pb	50		5	0	
Manganese, total, µg/L as Mn					50
Mercury, total, µg/L as Hg	2			3	
Nitrogen, total nitrate, mg/L	10			10	
Nitrite, total nitrite, mg/L				1	
pH, standard units					6.5–8.5
Selenium, total, in µg/L as Se	10			45	
Silver, total, µg/L as Ag	50				
Sulfate, dissolved, mg/L as SO_4					250
Zinc, total, µg/L as Zn					5,000
2,4–D, total, µg/L	0.1			0.07	

Notes:
MCL = maximum contaminant level
MCLG = maximum contaminant level goal
PMCL = proposed MCL
PMCLG = proposed MCLG
SMCL = secondary MCL
µg/L = micrograms per liter
mg/L = milligrams per liter